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ACTINISM.*

BY PROFESSOR CHARLES F. HIMES, PH.D.

Col. CHAS. H. BANES, Chairman of the Committee on Exhibitions introduced the lecturer with the following remarks:

LADIES AND GENTLEMEN:—It has been the earnest desire of those in charge of the preparations for this exhibition, to give it an educational character; and they have sought by all means at their disposal to develop this feature to the fullest extent. One of the most useful and popular means which they have adopted to attain this object, is the present course of lectures upon topics appropriate to the place and the subject of the exhibition, and the Committee in charge of this work have been most fortunate in securing the co-operation of a number of eminent men of science.

I have great pleasure in introducing to you Prof. Charles F. Himes, of Dickinson College, who will lecture this evening on the subject of "Actinism."

Prof. HIMES spoke as follows:

LADIES AND GENTLEMEN:—The branch of science which considers the chemical changes produced by the action of light—named many years ago by Herschel, Actino-chemistry—has been so developed

* A lecture delivered at the International Electrical Exhibition, October 2, 1884.

within recent years, that it has won its way to recognition as a most important, as well as interesting field of investigation. But, apart from its intrinsic interest, there seems to be an especial appropriateness in its consideration at this time, and in this place. Electrical illumination has converted night into day upon your streets, has rendered your shopkeepers independent of sunlight; and it promises, also, by reason of its richness in those very rays that effect chemical changes, to render those who employ the actinic power of light equally independent of the variable and uncertain light of the sun.

Our treatment of the subject this evening must necessarily be controlled by the limited time at our disposal, and it has seemed to me that the most may be accomplished by adopting as a general plan, as indicated in the syllabus, first, a rapid survey of the leading facts, as they present themselves in the development of the science, and the illustration of these by typical experiments, and then a consideration of these, as far as possible, in their connection, as explained by the wave theory of light. Uniform treatment of the subject is almost as necessarily excluded as exhaustive treatment, and it will be found necessary to pass by features of the highest interest, and possibly of even greater importance than those presented, without even an allusion. Again, whilst photographic processes and manipulations, as such, do not constitute the subject for our consideration, we will find it convenient, and even necessary, at times to employ the terms and processes of photography; but we will do so only in so far as they may assist in the discussion of those general facts and principles that constitute the scientific basis of all photographic practice.

The fact that a pure white compound of silver, called by the alchemists horn silver, by us silver chloride, darkens in the light, was the first observed chemical effect of light, and occupies, in this connection, the same place that the attractive power imparted to amber by friction occupies in the history of electrical science.

I have here, in a protected roll, a piece of paper, coated with a thin layer of this substance. I unroll it, as you see, in the mellow light of these incandescent lamps, without any precaution whatever. That light, comfortable as it is to the eye, is comparatively feeble in its effect upon silver chloride. But Mr. Knapp will expose it for a short time to the light of our arc lamp, and, that any effect produced may be more readily noticed, I will first cover it with this cardboard, with a design cut out of it, so that a portion of the paper will be com-

pletely protected, whilst the other portion will receive the full effect of the light, and we may thus have the advantage of the contrast. In giving this fact the prominence I do, as the first observed in this connection, I do not, of course, ignore the general observation of the effect of light upon animal and vegetable life. That forced itself upon the attention of man in all ages. The necessity of light for healthy animal and vegetable growth, for the production of color in the flower and bloom upon the fruit, of course could not be overlooked. But in all these cases the action of light is so complicated with so-called vital processes, controlled by so-called vital force, that there is scarcely a hint at its action *per se*. The darkening of this compound, noticed as well by miners in an ore of silver as by the alchemists in a laboratory preparation, was unique, in that it was entirely uncomplicated with mysterious vital processes, in that it was purely a laboratory experiment, that invited investigation by ordinary methods.

You notice now, as I uncover this paper, returned to me by Mr. Knapp, after exposure, as you have seen, to the light of the arc lamp, how the unprotected portion, represented by the design cut out of the cardboard, has been decidedly darkened. This has been accomplished in less than a minute. Any one conversant with photographic practice will understand what that means, and will be surprised at the wonderfully actinic power of this arc lamp. For this substance darkens but slowly in diffused sunlight. Now, just as the isolated observed fact in electricity awaited Gilbert to expand it into a branch of science, so this fact waited until, about a century ago, Scheele, the eminent Swedish chemist, undertook its systematic investigation, and did for actino-chemistry what Gilbert had done for electricity. He explained the change effected by light, *practically*, as we understand it to-day, as a separation of chlorine. But he did more. The query arose in his mind, whether all the rays of sunlight were equally effective. He investigated the problem experimentally. Availing himself of the beautiful discovery of Newton, he threw, by means of a prism, the particolored band of light called the spectrum upon the floor of the room, and in it placed powdered silver chloride. He found the effect greatest at the blue end. We have not sunlight at our disposal to repeat this experiment as he did; but we will avail ourselves of our arc light, which we have already tested as to its actinic power. The beautiful spectrum you now see upon the screen is similar to his. In it we will now test the actinism of the extreme ends—the blue and

the red portions. We will employ an ordinary photographic glass plate, sensitive to light, so that the result can be exhibited by the lantern upon the screen. But first, in this case, all our incandescent lamps must be turned off. The reason for this will be apparent as we proceed. Now, with the assistance of Mr. Knapp, as you see, one end of our plate is exposed behind one half of a stereoscopic negative in the red end of the spectrum, and now the other half is held in the same way in the blue end of the spectrum. The exposure in each case has not exceeded thirty seconds. I now pass the plate to the photographic assistant, to be developed, with the request that the developed plate be exhibited to us, in time, by means of the lantern upon the screen. Whilst we await the result I will consider some very natural queries that may have arisen. Why is this experiment conducted so differently from that of a moment ago? Why are the results not exhibited at once, as then? What is implied, in this connection, in the word "developed?" I would simply say, first, that not the slightest trace of the action of light would have been visible upon the plate just exposed, upon either end, even upon the closest and most careful examination. But, secondly, in response to proper chemical tests, called developers, an invisible effect, sometimes called a latent effect, or image, will become visible, that is, of course, if it has been produced.

It is the possibility of the production of such an invisible latent, but developable effect of the action of light that constitutes the grand discovery of Daguerre, a discovery that may well be regarded as the initial fact of modern photography, and one that renders Daguerre the central figure around which the facts in photographic history most naturally group themselves. In this statement I have no disposition to deny or detract from the merits of other investigators in this direction. After Scheele almost every chemist and physicist of eminence had experimented to some extent with compounds sensitive to light. Among them Davy, Wedgewood, Wollaston, Herschell, Niépce, Talbot and many others whose names we cannot even take time to recall. Many of these, or most of them indeed, worked much more scientifically than Daguerre; many of them had a great measure of success in some directions; but all efforts to fix an impression of the image formed in the camera obscura upon a sensitive surface were practically failures up to the time of Daguerre's discovery. It may, therefore, be allowable to give a more detailed account of it, in order to emphasize its historic prominence.

Daguerre was a scene painter in Paris, and an artist of considerable merit, and highly successful in his profession. About 1824 he was first seized with the infatuation to fix permanently the evanescent pictures of the camera, which he employed to assist him in his profession. Nothing already accomplished in that direction seems to have incited him, or encouraged him. How much he even knew of what had been done cannot be accurately stated, but this much can I think be said with certainty, that nothing already accomplished indicated in the remotest degree the possibility of discovery in the direction finally taken by him.

But now I am notified that our exposed plate is ready to be exhibited upon the screen, and we will have the opportunity to compare the effects of the red and blue ends of the spectrum upon it. We see in the picture upon the screen that there has been an impression upon that end of the plate. I do not recognize the picture* but what it may be matters not, it is the fact that an impression has been produced, that is the all-important fact for us. The photographic assistant informs us that this is the half exposed in the blue end, and now as he passes the other end into the lantern the blank upon the screen shows the absence of effect by the red rays.

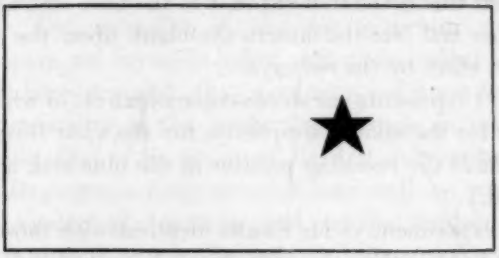
[Thus Fig. 1 represents our stereoscopic negative, in which a diagram is substituted for the sake of simplicity, for the view from nature, and in Fig 2 we have the resulting positive at the blue end, and the blank at the red end.]

So far our experiment yields results identical with those of Scheele's with silver chloride. But these effects, as I have already stated, were invisible when the plate left us; they have only put in an appearance under a treatment called *development*. And now let us return to the history of the discovery of this developable effect. Some portions of it remind us of those little bits of embellishment often thrown around the history of science, as well as civil history. I would hesitate to give it had I not strongest ground for belief in its authenticity. No alchemist had ever gone to work at a more unpromising task than that Daguerre had imposed upon himself. As years rolled on the passion only took deeper hold upon him. In spite of utter failures and discouragement of all kinds, for years, in loneliness and in secrecy, suspected of mental weakness, even by his wife, he kept on in

* It was a negative of Luray Cave, by C. H. James.

the same line of experiment. Finally one of those accidents, that only strike men who work their way across their path, brought him most remarkable success. One of his methods, in brief, was to subject polished plates of silver to the vapor of iodine until they became coated with a creamy film of silver iodide, then to expose this surface to the image in the camera; but always without the hoped-for effect. The plates thus exposed, were then stowed away in the rubbish closet until the supply was exhausted. They were then taken out, re-polished and re-exposed

FIG. 1.



R. FIG. 2. B.

in the camera with the same discouraging results. Upon one occasion, on removal of the plate from the rubbish closet, he found upon it, to his great surprise, the very image that had fallen upon it in the camera. He proceeded to investigate. He exposed another plate in the camera and placed it in the closet with a similar result. Then exposing one plate after another in the camera, and each time removing from the closet some article before stowing the plate in it, each time he found upon it the same faithful delineation of his camera picture. At last everything had been removed, and still the exposed plate placed in the closet exhibited the developed image. Some mercury spilled upon the floor of the closet alone remained. The magician was detected. The vapor of mercury developed the invisible or latent image on the exposed

iodized plate. For some reason or other, the mercury adhered to the portions acted upon by the light, and in proportion to the action of the light, thus rendering faithfully all the gradation of tones. The excitement in the scientific world upon the announcement of the success was intense. Capital, however, hesitated to patronize the invention; but Arago struck with the exquisite beauty of these first Daguerreotypes, and the promises of the discovery, undertook its advocacy, and the French legislature pensioned Daguerre and his co-laborateur Niépce, that it might present the invention as a gift to the world. The formal anannouncement of the process was made before one of the most brilliant assemblages of the French capital. But it may be asked:—after all, what was there so important in the discovery of an invisible effect that needed development? The great value lay in the rapidity with which this developable effect could be produced. Hours required before to produce the feeblest visible effect were now reduced to minutes, and even seconds. It was permitted to hope that portraits would become possible. The first successful attempts at photographic portraiture were not, however, made by Daguerre, but by that remarkable man, Dr. John W. Draper,* of New York. By his previous careful scientific investigations, he was prepared at once to see the importance of Daguerre's discovery and to utilize it. But these compounds as then produced were comparatively so slow to receive even the latent effect, that the subject was obliged to sit with powdered face in the bright sunshine.

But to return to the spectrum. The recognition of three classes of effects in sunlight is inevitable. Two of these, light and heat, accompanied as they are by corresponding sensations report themselves to us directly. The existence of the third, without any corresponding sensation, we may regard as first established on a scientific basis by the investigations of Scheele, and he also showed that it was not equally distributed throughout the spectrum. Herschell in his investigation of the distribution of heat found, that after the visible spectrum had ceased with the extreme red rays, there were still rays invisible, incapable of affecting the retina, but capable of producing heat, and Professor Langley recently, with his delicate "bolometer," pushing his investigations still further into this infra-red region of the spectrum, has demonstrated the presence of rays where their presence was hardly suspected before, in fact where extra-polation formulæ would not allow them to exist.† So on the

* "Draper's Sci. Memoirs," p. 215; "Philosophical Magazine," Sept. 1840.
† "Am. Jour. Sci.," vol. xxvii, p. 170, March 1884.

other hand Ritter, continuing the investigations of Scheele, found equally invisible rays in the ultra-violet portion of the spectrum, capable in the highest degree of producing chemical changes.

The diagram now upon the screen (Fig. 3) is intended to exhibit the distribution of these qualities of sunlight in the spectrum in a most general way. Although liable to misinterpretation, with care, it will serve a purpose, and will help in emphasizing the direction in which some of the most recent advances in practical photography have been made. The curved line *III* shows the variation in the intensity of the heating effect, with its maximum in the dark infra-red region; the curved line *I*, shows the same for the luminous or visual effect, with its maximum near the line *D*, in the yellow, and gradually fading out at the limits of the visible spectrum; the curve *II*, is intended to show the distribution of actinism, with its maximum in the violet and extending far beyond into the ultra-violet dark space, but feeble in the visible portion, and almost wanting in the yellow, about the line *D*. This last may be regarded as correct for the compounds that have been and are yet generally used in photography; just as Scheele demonstrated for the

FIG. 3.

direct effect upon the silver chloride, and as we demonstrated a few moments ago for the developable effect upon others. We have in consequence become habituated to speak of violet as actinic rays, and of the red and yellow as non-actinic. We will find how incorrect this is.

It was demonstrated many years ago by Dr. Draper, among others, that the effective rays in producing those changes upon which vegetable growth depends are not the violet, or ultra-violet, not the photographic rays, but rather the yellow and orange. Even the compounds of silver in common use, on more careful investigation, display different degrees of sensitiveness to the different colored rays. The diagram now upon the screen, after Capt. Abney (Fig. 4), exhibits this fact in regard to the three closely related compounds, silver chloride, bromide, and iodide, the basis of modern photography. The upper diagram, you will recognize as a reference diagram of the solar spectrum, with the principal Fraunhofer lines, and the corresponding colors indicated beneath

Now following the curves indicating the variation in the intensity of effect upon the compounds, the maximum for each seems to be about at the same point in spectrum, about the line *G*, in the blue. But the variation in intensity from this maximum point is different in each case. On the iodide the diminution is very rapid toward the violet, as shown by the abrupt fall of the curve, whilst on the bromide it is very gradual, the colors from *b* to *H*, from green to violet, impress the bromide more nearly equally, and would therefore be much more uniformly rendered in a photograph upon it. But there is another fact equally apparent in the diagram, the range of effect upon the bromide is greater, as is shown by the extent of the curve beyond *b* on the one hand, and *H* on the other. The bromide would receive, then, impression from colors to which the others would be insensitive. But in spite of these marked differences, the rays toward the blue end are in each case the most effective. It seemed to be generally accepted for a long time that whilst an actinic effect of some degree could be produced throughout the whole visible spectrum, that whilst every ray that can affect the retina is also capable of affecting to some extent these sensitive compounds, still the power to produce chemical change resided, for some reason, in the highest degree, for all compounds, in the more refrangible rays toward the violet.

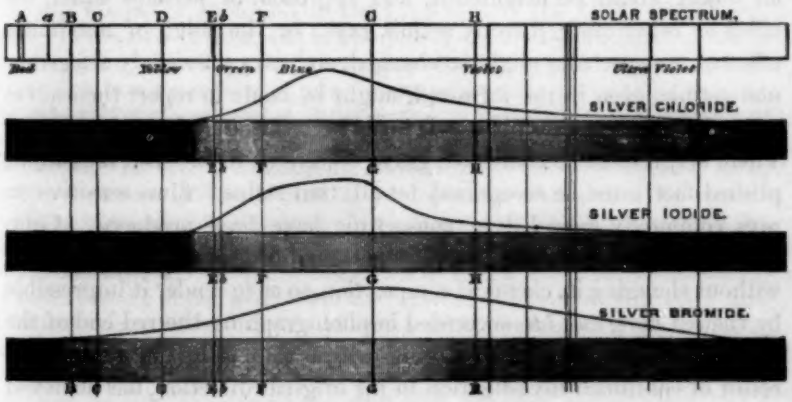


FIG. 4.

It seemed to be accepted almost as inevitable, that photography could never render faithfully the luminous or visual effects, the intensity of effect upon the retina, of the different colored portions of an

object, by proper shades in monochrome. That, for example, in a photograph of an orange tree, its bright yellow fruit, and its dark green leaves, would both be represented as equally dark, because practically equally non-atinic. So in the investigation of the spectrum by the aid of photography, that the actinic end alone would impress itself with all its details, and that for the infra-red, other modes of investigation would have to be resorted to. Directed by a theory, which we will notice presently, Dr. H. W. Vogel,* of Berlin, succeeded, in 1873, in increasing the sensitiveness of these same common compounds of photography to the less refrangible, non-actinic rays. The process is so simple that it surprises. The light that acts chemically is the light that is absorbed by the particular substance, or, light to produce an effect must be absorbed. This condition was first enunciated and demonstrated by Dr. Draper.† Dr. Vogel stained the sensitive film with some transparent dye. That certainly meant absorption of certain selected rays; of the red, if he pleased so to select the dye. Just as the blue glass, which I now place in front of our arc-light, absorbs certain rays, and cuts them out of the spectrum upon the screen, as you see. (See Fig. 7.) He reasoned, then, that these absorbed rays may become photographically effective, and produce, or increase the intensity of, the impression upon the sensitive compound. If red was absorbed the effect of the red portions of an object would be heightened, and approach, or perhaps equal, the effect of other more directly actinic rays; or the point of maximum effect in the spectrum might be changed, and rays previously altogether non-actinic, even in the infra-red, might be made to report themselves upon the photographic plate. It is not necessary to indorse this theory. There are, it must be confessed, grave objections to it. But the accomplished fact must be recognized by all, that stained films sensitive to rays commonly regarded as non-actinic have been produced. Capt. Abney,‡ by a different method, has also modified the bromide of silver, without changing its chemical composition, so as to render it impressible by the red rays, and has succeeded in photographing the red end of the spectrum. But Dr. H. W. Vogel,§ within the last few months, as the result of continued investigation in his original direction, has achieved a success in practical photography which, in its results, seems only second

* See foot-note p. 355.

† "Draper's Sci. Memoirs," p. 230; "Philos. Mag.," Sept., 1841, p. 435.

‡ "Chem. Effect of Spectrum." Eder, p. 49.

§ See foot-note p. 355.

to that of Daguerre, and which leaves nothing great beyond to be accomplished, except the fixing of the colors themselves. A new word is necessary to describe this phase of the art. The term isochromatic photography has been introduced. A photography that will give you a picture of the orange tree with its yellow fruit and green leaves, not in their natural colors, but what is almost as desirable, in their natural shades, according to their luminous or visual intensity, the intensity of the impression they make upon the retina of the eye. A photograph of an oil painting, by the old process, could not but be unsatisfactory. Its yellows would be dark, its warm reds would be black, whilst its deep blues, that hardly affect the eye, would present themselves among the high lights of the picture. By the isochromatic process the reds, yellows and blues of the painting are all represented by shades that faithfully represent their luminous or visual effect. An artist whose pictures have been copied by it expresses himself as fully satisfied with the results, which is certainly a very valuable indorsement. Prof. Vogel claims to be able to produce eightfold the effect by yellow light that is produced by blue light. From the dye employed it is spoken of as the azaline process. What an advance since the days of Scheele, or even of Daguerre!*

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* The term orthochromatic has been proposed by Dr. Eder, and is growing into use, instead of isochromatic, since it is equally descriptive of the peculiarity of the new process, and is free from confusion due to previous use in a different connection. The increasing interest in this process, and its expansion into a commercial one, for orthochromatic plates are advertised for sale, call for a somewhat fuller notice in regard to it. The credit of having directed investigations into this channel unquestionably belongs to Dr. Vogel. In 1873 (*Philadelphia Photographer*, vol. ii, p. 25, Jan., 1874; *Photographische Mittheilung*, 1873; *Photographic News*, 1874), in experimenting upon alkaline development on silver bromide dry plates, with the spectrum, he found in certain cases unusual sensitiveness to the so-called non-atinic rays. By careful investigation he traced this to the preservative, or other coating of the plate. He had previously enunciated as a law that a sensitizer should be capable of acting as an absorbent of the liberated halogen, and, at the same time, of the light which acts photographically, or, that chemical and optical absorption should accompany each other. Directed by this, by dyeing the film with coraline, he produced plates sensitive to yellow, and, by the use of an aniline-green, plates highly sensitive to red, and concluded that silver bromide could be rendered sensitive to any color. A picture of a blue ribbon on a yellow ground, which by the ordinary process was white on a dark ground, by his process was dark on a light ground. It was necessary to put a yellow glass in front of the lens to tone down the blue, otherwise, if both colors were of equal actinic effect, no

[In the absence of an illustration by Dr. Vogel's process, we are fortunate to have placed at our disposal, since the delivery of the lecture, one by Mr. F. E. Ives of Philadelphia, by his myrtle-chlorophyl

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contrast would have been obtained. In these earlier cases sensitiveness to some particular selected color seems to have been secured rather than equal sensitiveness to all colors. Eosine, suggested afterward by Major Waterhouse, was employed with better success, and Dr. Vogel's continued investigations led to his perfected isochromatic process, in which azaline was employed, in 1884 (*Philadelphia Photographer*, Aug., 1884, p. 251; *Id.* Sept., p. 284). Results by this process of the most varied character on exhibition at the New Orleans International Exhibition are pronounced "marvelous" (*Photo. Times*, Feb. 27, 1885). The announcement of the effect of dyes for this purpose by Vogel was followed by experiments in the same direction by Abney, Waterhouse, Lea and others, and whilst his theory of optical sensitizers was not accepted, nor in all cases could the precise results obtained by Vogel be reproduced, the demonstration of the possibility of isochromatic effects in this way is conceded to him. Dyed films were undoubtedly suggested and used by M. Carey Lea prior to their employment by Vogel (*Anthony's Phot. Bulletin*, Jan. 10, 1885, p. 6; *Silliman's Am. Jour. Sci.*, Jan. 1885, p. 53), but for an entirely different purpose (the prevention of blurring), and without noticing any sensitizing effect to non-atinic rays, if any occurred, and without even hinting at any such possible effect of the dye. It has recently been shown by Lea (*Ibid.*) that the haloid salts of silver are capable of forming compounds with some coloring matters similar to lakes, by use of which plates sensitive to color may be prepared. This seems to be in accord with Abney's theory, that the increased sensitiveness to color is due to the formation of compounds in Vogel's experiments (*Chem. Effects of Spectrum*, Eder, p. 39). In 1879, F. E. Ives, of Philadelphia (*Philad. Photographer*, Dec., 1879, p. 365), published a process in all its details, in which chlorophyl obtained from the leaves of the blue myrtle was employed as the dye, and a cell with glass sides containing a solution of bichromate of potash was substituted for the yellow glass of Vogel. The former has the advantage that the strength of the solution can be readily adapted to the quality of the plate and the character of the subject. He lays great stress upon the chlorophyl from this particular plant, and prepared according to his method, and claims that it was the first perfected isochromatic process, and even unequalled in its results by Vogel's azaline process, which it antedates several years. The specimen by his process herewith presented (see frontispiece) certainly exhibits wonderful capabilities of the process. Becquerel, in 1875 (*Chem. Effect of Spectrum*, Eder, p. 41; from *Comp. Rend.*, vol. lxxix, p. 189), found that chlorophyl acted as a sensitizer to the non-actinic rays. Isochromatic plates by any process are slower than ordinary plates, and the yellow screen seems necessary to tone down the blue, but they are susceptible of many applications peculiarly their own. They have been suggested for copying old manuscripts as well as oil paintings.

process first published in 1879,* and in which we are at a loss which to admire most, the isochromatic effect, or the exquisite photo-typographic prints, made by the well known process of the same gentleman. The subject was a highly colored chromo-lithograph of a lady, wearing a bright scarlet hat with purple feather, a yellow-brown cape, and a dark-blue dress. The effect of the non-actinic colors has been even exaggerated, purposely, to demonstrate the capacity of the process.]

What is the nature of the changes produced by light? Scheele demonstrated, if he did not express it in the terms that we employ to-day, that silver chloride was decomposed by the action of light, that its rays dissected off atoms of chlorine, or to use a more modern term that it was a case of chemical *dissociation*, and that a lower chloride of silver was formed of a violet color. With reference to the effect, subsequently discovered, upon bromide and iodide of silver, opinion was at first inclined to call the change a physical one, and not chemical, a change in the arrangement of the molecules of the substance, in their relations to each other, not a change in their kind; afterward opinion was divided between physical and chemical change, whilst to-day there is general agreement that the change is essentially the same as that experienced by the chloride, namely chemical dissociation or decomposition, that bromine and iodine are separated. The difference between the chloride and iodide, or bromide, lies in the fact, also first clearly stated by Professor Vogel,† that the latter demand, as a favoring condition, that something should be present to dispose of, to absorb, the liberated iodine or bromine.

Indeed iodide of silver, without the presence of some such an absorbent, is not acted upon by light, and the bromide but slightly. A photographic collodion plate always contains such an absorbent in the free silver nitrate solution adhering to it. If an iodized sensitive plate is thoroughly washed, it becomes insensitive, but if now it be dipped into a solution of tannin it becomes sensitive, even when dried. Tannin acts as an organic absorbent of iodine. Photographic collodion dry plates rest upon the presence of such chemical absorbents, as sensitizers, and which from their action we called *chemical sensitizers*. To the sensitizers, previously described, that render isochromatic photography possible, the dyes applied to the film, the name *optical sensitizers* has been given by Dr. Vogel, on the ground that they do

* See foot-note p. 355.

† "Photographic News," 1865, p. 209.

not act chemically, or as absorbents of iodine, or to state him more fully, because there is considerable discussion going on at this point, they do not act exclusively or principally as chemical absorbents, but by reason of their power to absorb particular colored rays, and thus to increase their effect by increasing the quantity, so to speak, of that particular light acting upon the chemical compound with which they are associated.

I confess there are difficulties, theoretical and practical, in the way of accepting this theory of optical sensitizers, but it does not minify the discovery of Dr. Vogel to disagree with him on this point, and so eminent an authority as Captain Abney rejects altogether the term optical sensitizer, and as already stated, he has succeeded in photographing the red end of the spectrum by modifying the silver bromide upon an entirely different plan.*

There is another very remarkable actinic effect that calls for a passing notice. It might be inferred, that if the action of light for a short time produces these feeble but developable effects, the action for a longer time would increase the effect, that a photographic plate exposed to a view in the camera would only give a more easily developed impression the longer the exposure. It is true that the number of molecules decomposed is proportional to the action of the light, that light does all the work of decomposition, that one decomposed molecule does not propagate, so to speak, the effect to others, but still it is a fact well known to photographers, and generally called *solarization*, that a reversed effect is produced upon a plate exposed for too long a time; that on such a plate, the sky, for example, the high light of the picture, that should produce the most intense effect, that should darken most under development in the negative, becomes thin and transparent. And in photographing the solar spectrum it is possible to produce these reversed effects, so that the dark lines receive a heavier deposit, and instead of being transparent in the negative, as might be expected, are more opaque than the luminous portions of the spectrum. A slight previous exposure of the plate to diffused daylight, before exposing in the camera, is favorable to this reversion of effect.

We can only say that one explanation of this contradictory phenomenon is, that there is an oxidizing action of the rays subsequent to the first effect of decomposition, and this brings us now to notice a

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* Chemical Effect of Spectrum, Eder, p. 49.

radically different class of effects of light from those that we have been considering. I have here upon the table, protected from the light by a slight covering, a series of little glass bulbs such as I hold in my hand, with tubes at each side, connected with each other by gum tubing, and finally with a glass tube leading out through the cork of a glass flask, or decomposing cell, which contains hydrochloric acid. Into this, through holes in the cork, protected by glass tubes, dip carbon rods, the flask being closed air-tight. The carbon rods are connected with the poles of the battery upon the table. The current of electricity passing through the hydrochloric acid, as is well known, separates the elements of which it is composed, and the hydrogen and chlorine pass out through these bulbs non-combined, but simply mixed as gases, and after a time these bulbs will be filled with a mixture of the gases in the proportions in which they were present in the hydrochloric acid. Now, singular to say, what the electricity has done light can undo, or *vice versa*. I place one of these little globes, containing the mixed gases, with the end of one tube underneath the colored liquid in this little bottle, whilst the other tube is tightly closed. I now turn on this incandescent light near the bulb, the rise of liquid into the bulb shows that the gases have combined to that extent, and that the resulting compound, the hydrochloric acid formed has been absorbed by the liquid. The rapidity of the combination depends upon the actinic intensity of the light. If placed in sunlight, or even the glare of the arc-light, they would combine with explosive rapidity, and we would fail to follow the experiment as we can in this way. Now this combining action of light upon hydrogen and chlorine is distributed throughout the spectrum in the same manner as the dissociating action upon silver chloride. If we could determine the degree of one kind of effect produced by a given light, we would have determined it for the other.

I have selected this experiment, and have performed it as I have, to assist in illustrating one of the various methods for measuring the actinic intensity of light. The effect upon the eye, the photometric effect, does not afford any means of judging of actinic effect. As we have seen, the rays that effect the retina have feeble actinic effect; it is in most cases the invisible rays that do the photographic work. Now the quality of sunlight in this respect varies from day to day and hour to hour, as well as with the seasons, with meteoric conditions that do not report themselves to the eye, or to ordinary meteoro-

logical instruments. Nothing could be more desirable to those employing this agency, than some method, or instrument rather, by which actinic intensity of sunlight could be readily tested at any time.

That remarkable man, Dr. John W. Draper, of New York, who never simply did a little and suggested a great deal more for some one else to do, as is so often the case, first used this fact of the combination of hydrogen and chlorine under the action of light for actinometric purposes.* He devised an instrument, and made determinations of surprising accuracy, and Bunsen and Roscoe† long afterwards adopted his plan and expanded it so as to establish *actinometry* on a thoroughly scientific basis.

I call your attention now, by way of illustration of one mode of application of these facts, to a piece of apparatus, devised by Dufour,‡ in which this apparent antagonism between the electrical current and actinism is utilized for measuring the latter. In the diagram (Fig. 5)

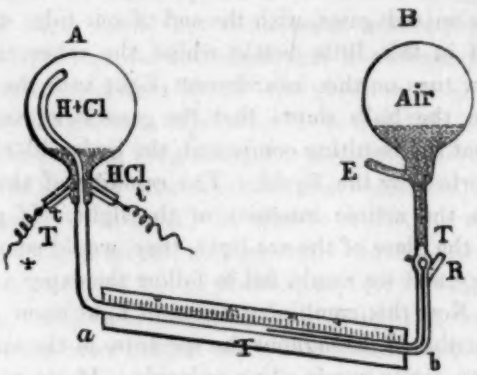

FIG. 5.

A and *B* are glass bulbs connected by a small glass tube *T*, *T*, *T*, which passes up through the neck of *A*, as indicated, and opens into the bulb near the top. This bulb is partially filled with hydrochloric acid, *HCl*, with a mixture of hydrogen and chlorine gases, *H*+*Cl*, sensitive to light above. In the other bulb *B*, an equal volume of air is enclosed over sulphuric acid. The stop-cock at *R* being opened, the sulphuric acid

* "Draper's Memoirs," p. 245; "American Jour. Sci.," vol. xlvi; "Philos. Mag.," Dec. 1843.

† "Die Actinometrie, Pizzighelli," p. 13; "Poggendorff Annalen," Vol. c., pp. 43, 481; "Watts Dict. of Chem.," Vol. iii, p. 678.

‡ "Die Actinometrie, Pizzighelli," p. 37; "Photo. News," 1881, p. 158.

will take a fixed position in the horizontal graduated connecting tube, and serve as an index. Now upon exposure of the bulbs to light, a portion of the gaseous mixture in *A*, would combine, and the resulting hydrochloric acid gas formed would be at once absorbed by the liquid, and the sulphuric acid index would move toward *A*. Any disturbing influence of heat upon the experiment is eliminated by the equality of effect on both bulbs. But now, if instead of simply allowing light to produce combination, we at the same time produce a counter effect by means of an electrical current passed through the *HCl*, by means of small carbon rods inserted through the lateral tubes *t*, *t*, and connected with the poles of a battery, by varying the current until combination and decomposition are equal, the index will be rendered stationary and a comparison of the strength of electrical currents required in two cases to produce this condition will be a comparison of the actinism of the light in any two cases. It is almost needless to remind you that there are many substances adapted to actinometric purposes. Silver chloride paper, such as we used in our first experiment has been employed. Ferric oxalate, which, under the influence of light, decomposes and evolves carbon dioxide, which may be measured or estimated by loss, was also suggested and used by Dr. Draper. But there is still need of a convenient and reliable actinometric method. But in any case it is plain from what we have already said that an actinometer adapted to one set of rays would not be reliable for others; or one that would give the intensity of effect at a given time upon one substance would not necessarily give the effect upon another substance.

We have thus rapidly noticed some of the leading actinic effects of light. How are these effects produced? This question brings us face to face with the other questions: What is the mechanism of light? What is the ultimate constitution of matter? We have no difficulty in accepting the undulatory theory of light so clearly set forth by Sir William Thomson* a few days ago. Let us assume in round numbers that 800 million million of undulations per second of the hypothetical ether, that pervades all space and all matter, produces the sensation of violet and 400 million million produce that of red; that beyond violet there are other undulations still more rapid, and below red slower ones, neither of which report themselves to us as light, that do not affect the retina of the eye. These wavelets beat upon the sensitive compounds we

* Lecture on "Wave Theory of Light," Academy of Music. *Vide* this JOURNAL, Nov. 1884.

have been considering; these are composed of groups of atoms called molecules; these molecules are shaken until each one looses an atom or two, new groups of atoms, new molecules are formed, that is a new substance is formed. It may have a color different from that of the original, perhaps, as sub-chloride of silver, or different attractive properties, as the changed iodide for mercury in Daguerre's process, or for silver just reduced from its solution as in the ordinary collodion process. We are surprised sometimes at the rapidity of the action of light at the so-called instantaneous photographic effects; the pictures of animals in motion, of bombs bursting in air, etc. Let us look at these in the light of our theory, and may be we will find that after all these effects are rather slow. I now call your attention to a photograph, upon the screen, of sparks of a Holtz machine (Fig. 6.). I have selected

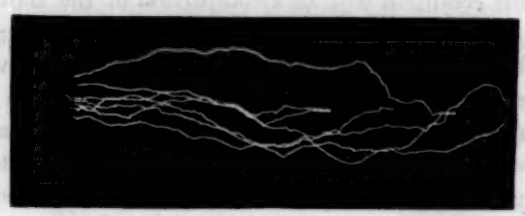

FIG. 6.

this because these sparks are of shorter duration than that any instantaneous drop or slide could be made to give. They impressed themselves upon an ordinary collodion plate in the camera as they passed. Suppose we assume $\frac{1}{20\,000}$th of a second as the time, and we will certainly be within bounds. That is a fraction difficult to comprehend. Sir William Thomson* told you a few days ago, that it was easy to understand large numbers, just as easy to comprehend a million-million as a million, that it is the negation of infinity that is difficult to understand. But this small fraction will trouble us. Our mental dividing engine fails in performance as we work toward zero. The twenty-thousandth of a second is so small that it eludes our mental grasp. Now astronomers when wrestling with celestial distances frequently resort to artifices to bring them within the range of comprehension. They fire imaginary cannon balls at the sun, and convert the vast distance into time by calculating the duration of its flight at its greatest

* Lecture at Academy of Music, Sept. 29th. *Vide* this JOURNAL, Nov. 1884, vol. cxviii, p. 327.

velocity; again they build imaginary railroads to the fixed stars, and calculate the generations that will be born and perish before the train reaches its destination, or to bring the matter down still nearer the ordinary apprehension, they calculate the fare and state it in terms of the national blessing as a unit, and thus put it on a dollar and cent basis, and we allow ourselves to be persuaded that we have mastered the difficulty. Now without resorting to any artifice, without changing the character of our phenomenon, but simply looking at it from another point of view, let us regard the effect as a space effect of light instead of a time effect. Light has a velocity in round numbers of 190,000 miles per second, that would be 190 miles in one thousandth of a second, 19 in one ten-thousandth, or say 10 miles in our $\frac{1}{20\,000}$th of a second. Ten miles of light drive in upon our plate in that time; or if we held the corpuscular theory of light of Newton, a chain of these little pellets ten miles long would have delivered themselves upon the sensitive surfaces. Ten miles is comprehensible, one mile is, so that we could easily conceive of an effect in one-tenth of the time allowed to our electric sparks. But let us take another look at it. Light is not corpuscles but undulations, tiny wavelets, ripplets of ether, 800 million-million in a second for violet, a number we can easily understand, as Sir William Thomson has told us; that would make 800 thousand-million in one thousandth, eighty thousand-million in one ten-thousandth, or 40,000 million impulses striking upon our sensitive molecules in our $\frac{1}{20\,000}$th of a second. Surely that number should produce an effect. We can readily conceive that one thousand-million wavelets might produce an appreciable effect. They would only represent one eight-hundred-thousandth of a second, say one millionth of a second. That would seem, then, to be ample time to produce a photographic effect. Theoretically, we would hardly fix it as a limit of photographic sensitiveness, an encouragement certainly to instantaneous photography; for although the light of the sparks was and intense, the waves sent out by it have great amplitude, the plate that they have impressed is comparatively insensitive, not such as we would employ ordinarily to receive an instantaneous impression.

But it may be said these wavelets are very small, but so are the portions of matter upon which they operate, molecules that not only elude our grasp, but almost defy calculation, and still smaller atoms, the components of these molecules. The action of these waves of light upon matter may not, unfitly, then be compared to that of the

waves of the ocean upon the shore. But to get some notion of how these wavelets may act, let us resort to a coarse mechanical contrivance that will exhibit transfer of energy. These two balls, or pendulums, are connected, by suspension, on this wire stretched across the stage. I cause the one to vibrate, you notice that the other ball soon begins to vibrate, and also that its motion increases. Now if you turn your attention to the first, you will notice that its motion is decreasing at the same rate that that of the second is increasing. Now the second has acquired all the motion of the first, the first has ceased moving, and now the motion begins to be returned by the second to the first. I have arranged these balls so that either is, so to speak, in a peculiarly receptive condition with reference to the motion of the other. They are pendulums of equal lengths, of the same periods of vibration. I now change the length of one, by sliding the second ball upward on its supporting cord. I vibrate the first again, the second as you see takes motion again; the first looses, but for a much shorter time, and in a much smaller degree. Our second ball fails to take all the motion from the first. It is not as receptive as it was before. By similar experiments with this cord, containing two balls, by varying the positions of the balls, we see that there is a jarring of the combination, a movement very dissimilar to that of our two balls at first.

Now a luminous body transmits energy through the ether as a medium, as these balls do through the wire. The molecules of matter, composed of atoms of different kinds, may be in a receptive condition for vibrations of ether of a certain frequency, or they may be jarred, as it were, by these vibrations; atoms, or even groups of atoms, within the molecule may recognize their periods of vibration, and take up motion to such a degree as even to be thrown out. We can thus conceive of many ways in which molecular disruption could be brought about, which would mean chemical change.

But there is another phenomenon, beautiful in itself, and not only closely related to the subject in hand, but that seems to form a sort of a stepping-stone from this gross mechanical illustration to the actinic effect upon molecules. I have said that in this spectrum on the screen, far beyond the violet, there is a region of chemical activity but of darkness, where the photographic plate is impressed long after the retina ceases to be affected. Now if I were to pass out into this dark ultra-violet space, this paper, coated with sulphate of quinine, or other suitable substance, it would become visible, would *fluoresce*, would take

up these rapid vibrations of ether, and in some way render them visible, or, to express it better, would cause them to produce a visible effect.

Without taking time to perform the experiment in this way, because from the feebleness of the light it would be unsatisfactory to you, I will get an abundance of these rays by another method. This blue glass, that absorbs almost totally the other rays, allows these ultra-violet rays to pass. As I insert it in the path of the light that passes through the prism you see what portion of the spectrum it transmits. I now place this glass, before the arc light (by opening a side door of the lantern), and it casts only a deep blue, feebly luminous illumination upon the objects behind us. Now, whilst Mr. Knapp holds the blue glass in position, you notice that this white cardboard appears of a deep, feebly-luminous, blue. I now dip my brush into a solution of sulphate of quinine, and as I draw upon the card with the brush, you see how the tracings of the brush spring out in beautiful visible lines upon the dark-blue background of the card. The quinine solution reveals the presence of these ultra-violet rays; it somehow drags these rays down from the invisible into the visible portion of the spectrum, brings them within the range of retinal effect.

But now, what is equally surprising, though on reflection it is what we should expect, when the quinine brings these rays within the range of vision, it in so far removes them from the actinic field. In so far as they are made to affect the retina, in so far they cease to affect the sensitive plate. A photograph of this card, as it now appears in this ultra-violet light, with its luminous tracings of the brush, would give you dark letters upon a white ground, just as if drawn with ink; not as dark as with ink, but still deeply shaded, as they have been photographically degraded below the ultra-violet ground on which they are formed.

We have upon the wall much larger designs, kindly placed at my disposal by Professor Henry Morton, so well known in your city, of the Stevens Institute, of Hoboken. The two floral designs upon my left are of especial interest. The one is traced with thallene, a fluorescent substance, first isolated by Professor Morton; the other is formed of yellow paper. In the light of our electric arc lamp the paper design is most decided. We now illuminate with our ultra-violet light, by interposing the same blue glass; the thallene design springs out in beauty from the dark ground, by degrading the light into the region of vision; the paper design becomes almost invisible, having only the feebly luminous blue light to reflect. Briefly, what is the explanation

of this phenomenon, and what its bearing? The investigations of it by Professor Stokes are classical. His figure will help us. Imagine a number of vessels at rest upon a perfectly quiet sea. Suppose a series of waves, without any wind, originated by a storm afar off, propagated by the water, reaches the vessels; these will begin to swing back and forth, but in their own time, not necessarily the periodic time of the impinging waves. They would become new wave centres, sending out waves of their own period. So, in fluorescence, the molecules of sulphate of quinine, for example, struck by the rapid ethereal wavelets of the ultra-violet, begin to swing; but they vibrate in slower periods, because it is their nature, and originate waves of ether of their own rate, slower than the 800 million-million per second of the ultra-violet, but more rapid than 400 million-million, the limit of the visible spectrum at the other end. It originates, in other words, visible light, the violet is not changed into blue and yellow, it has simply produced an effect, and in so doing has ceased as such. The light that produces fluorescence is just as truly absorbed as that that produces chemical effect.

Fig. 7.

By comparing, in the diagram on the screen (Fig. 7), the absorption spectrum of the cobalt glass employed (1), and that of the sulphate of quinine (9), you will see that what the cobalt glass allows to pass beyond the violet, the quinine absorbs, and in absorbing fluoresces. We have, then, in this phenomenon a stepping-stone between our pendulum experiment and chemical effect. We are here dealing still with molecules, but molecules taking motion from each other as the pendulums did, but their atoms still hold together in the same molecular groups in spite of their motion, the sulphate of quinine still remaining quinine. The effect seems just short of chemical effect. This subject of fluorescence, and the closely related one of phosphorescence, is so attractive that it would hold us; but it has served our purpose for this evening; and, as we have already much exceeded our time, we must leave this subject of light in its chemical relations, with many points of interest untouched, and with thanks for your attention to the necessarily hurried, and incomplete presentation of so important a subject.

ISOCHROMATIC PHOTOGRAPHY.*

By Fred. E. Ives.

It is well known that the ordinary photographic processes do not reproduce colors in the true proportion of their brightness. Violet and blue, photograph too light; green yellow, orange and red, too dark. For a long time it was believed to be impossible to remedy this defect; and even when it became known that bromide of silver could be made more sensitive to yellow and red by staining it with certain dyes, the subject received very little attention, because it was also known that the increase of sensitiveness was too slight to be of practical value in commercial photography.

Dr. H. W. Vogel, who was one of the first, though not the first, to devote attention to this subject, announced, in 1873, that he had succeeded in making a yellow object photograph lighter than a blue or violet one, by using a silver-bromide plate stained with coraline, and exposed through a yellow glass. The plate showed no increased sensitiveness to red, and the experiment, although of considerable scientific interest, did not indicate a practically useful process.

In the spring of 1878 I became interested in this subject, and tried to discover a method of producing plates which should be sensitive to all colors, and capable of reproducing them in the true proportion of their brightness. I commenced by trying nearly all the color sensitizers which had already been suggested, in order to learn which was the best, and then, if possible, *why* it was the best, as a guide to further research. Chlorophyl was the only thing I tried which was sufficiently sensitive to red to offer any encouragement in that direction; but the solution which I obtained was weak and unstable, and far from being a satisfactory color sensitizer. Hoping to obtain a better solution with which to continue my experiments, I made extracts from many kinds of leaves, and found that a solution from blue myrtle leaves looked better and kept better than any other, and when it was applied to the silver-bromide plates they became remarkably sensitive, not only to all shades of red, but also to orange, yellow and green. By placing in front of the lens a color-screen consisting of a small glass tank containing a weak solution of bichromate of potash, to cut off

* Read at the stated meeting of the Franklin Institute, March 18, 1885.

part of the blue and violet light, I obtained, with these chlorophyl plates, the first photographs in which all colors were reproduced in the true proportions of their brightness. But my chief desire at that time was to realize a method of producing from any object in colors a set of three negatives, in one of which the shadows should represent the blue of the original, in another the yellow, and in another the red, in such a manner that transparent pigment prints from these negatives—blue, yellow and red—would, when superimposed on a white surface, represent not only the lights and shadows, but also the colors of the object. This had already been attempted by others, who failed because their plates were not sufficiently sensitive to red and yellow.

Having succeeded perfectly in my undertakings, I published my discovery in 1879,* explaining how to prepare and use the chlorophyl plates, in connection with the yellow screen, for the purpose of securing correct photographs of colored objects.†

So far as I know, nobody tried the process. Nearly five years later Dr. Vogel announced that, after eleven years of investigation, he had at last realized a successful process of this character, and that this new process of his, was the "solution of a problem that had long been encompassed with difficulty." This publication attracted a great deal of attention, and gave me occasion to again call attention to my process,‡ and point out that it was not only the first practical solution of this problem, but the only truly isochromatic process ever discovered. Dr. Vogel's new process was not only no better in any respect, but the plates were insensitive to scarlet and ruby-red, and therefore would not photograph all colors in the true proportion of their brightness.

My method consists in treating ordinary collodio-bromide emulsion

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* *Philadelphia Photographer*, December, 1879, p. 365.

† I intended this publication to be a very full and explicit one, and it was sufficiently so to be perfectly understood by most who saw it; but some may think I did not sufficiently emphasize the importance of using the particular kind of chlorophyl which I mentioned. In a brief communication to the editor of the *Photo. News*, in 1883, I described some experiments with eosine as a color sensitizer, and then called attention to the superiority of blue-myrtle chlorophyl for this purpose, stating that I had not been able to secure such results with any other kind of chlorophyl, and that a fresh solution from fresh leaves must be used to secure the greatest possible degree of sensitiveness. See *Photo. News*, Nov. 1883, p. 747.

‡ *Photo. News*, London, September 5, 1884, p. 566, and *Year Book of Photography* for 1885, p. 111.

plates with blue-myrtle chlorophyl solution, exposing them through the yellow screen, and then developing them in the usual manner. The emulsion which I have employed is made with an excess of nitrate of silver, which is afterward neutralized by the addition of chloride of cobalt; it is known as Newton's emulsion. I now prepare the chlorophyl from fresh blue-myrtle leaves, by cutting them up fine, covering with pure alcohol, and heating moderately hot; the leaves are left in the solution, and some zinc powder is added, which helps to keep the chlorophyl from spoiling. I have a bottle of this solution which was prepared about six months ago, and now appears to be as good as when first made.* A glass plate is flowed with the emulsion, and as soon as it has set, the chlorophyl solution is applied for a few seconds, after which the plate is washed in pure water until smooth, when it is ready for exposure.

My color-screen consists of a small plate-glass tank, having a space of $\frac{3}{16}$ of an inch between the glass, filled with a solution of bichromate of potash about one grain strong. I place the tank in front of the lens, in contact with the lens-mount. The advantage of this tank and solution is that it can be more easily obtained than yellow plate glass, and the color can be adjusted to meet any requirement.

The plates require about three times as much exposure through the yellow screen as without it, and may be developed with the ordinary alkaline pyro-developer.

In order to illustrate the value of this process, I made two photographs of a highly-colored chromo-lithograph, representing a lady with

* I originally recommended chlorophyl extracted from dried leaves, because I had not yet learned how to preserve the solution for more than a few weeks,—and at some seasons it would be difficult, if not impossible, to obtain fresh leaves. The tea organifier which I recommended is also a color sensitizer, and when it is used in connection with the chlorophyl from dried leaves the plates are as sensitive to red as can be safely prepared and developed in the light of an ordinary photographic "dark-room." Plates prepared with chlorophyl from fresh leaves do not require treatment with the tea organifier to secure this degree of sensitiveness. Recently I have used the tea organifier and some other sensitizers, in connection with the solution from *fresh* myrtle-leaves, and in this way have produced plates having such an exalted color sensitiveness as to be unmanageable in ordinary "dark-room" light. Possibly, such plates might be prepared and developed in total darkness, by the aid of suitable mechanical contrivances, but I am not sure that they would work clear even then, because they appear to be sensitive to heat as well as to light.

a bright scarlet hat and purple feather, a yellow-brown cape and a dark-blue dress. One, by the ordinary process, represents the blue as lighter than the yellow-brown, the bright scarlet hat as black, and the purple feather as nearly white. The other, by the chlorophyl process, reproduces all colors in nearly the true proportion of their brightness, but with a slight exaggeration of contrast produced purposely by using a too-strong color solution in the small tank. These photographs are herewith reproduced. (See frontispiece.)

I also made two landscape photographs, one by the ordinary process, and the other by the chlorophyl process, exposing them simultaneously. In the ordinary photograph, distant hills are lost through over exposure, yet the foreground seems under exposed, and yellow straw stacks and bright autumn leaves appear black. In the chlorophyl photograph, the distant hills are not over-exposed, nor is the foreground under-exposed; the yellow straw-stacks appear nearly white, and bright autumn leaves contrast strongly with the dark green about them.

To test the relative color-sensitiveness of plain emulsion plates, plates stained with eosine, and plates stained with the blue-myrtle chlorophyl, I exposed one of each kind through the same yellow screen, giving each five minutes exposure, on the same piece of copy, which was the chromo-lithograph already described. The plain emulsion plate showed only the high lights of the picture, after prolonged development. The eosine plate was under-exposed, but brought up everything fairly well except the scarlet hat, which came up like black. The chlorophyl plate was over-exposed, brought out all colors better than the eosine plate, and gave full value to the bright scarlet of the hat, the detail in which was beautifully rendered.

Dr. Vogel advanced the theory that silver-bromide is insensitive to yellow and red, because it reflects or transmits those colors; and that it becomes sensitive when stained, because of the optical properties of the dyes. He afterwards admitted that only such dyes as are capable of entering into chemical combination with the silver-bromide proved capable of increasing its sensitiveness to color, but he held to the theory that the optical properties of the compound were the cause of its color-sensitiveness.

I have shown that the color-sensitiveness can be produced by treatment with an organic compound which has none of the optical properties characteristic of dyes; and that chlorophyl, which absorbs only red light, greatly increases the sensitiveness also to yellow and green.

There is, therefore, good reason to doubt if the color-sensitiveness is ever due to the optical properties of the dye or combination.

Attempts have been made to produce isochromatic gelatine dry plates which, while many times more sensitive to white light than my chlorophyl plates, shall also show the same relative color-sensitiveness. Such plates would be very valuable but for one fact; it would be necessary to prepare and develop them in almost total darkness. Gelatine bromide dry plates extremely sensitive to yellow, but *comparatively insensitive to red*, might be used to advantage in portrait and instantaneous photography, because they could be safely prepared and developed in red light; but when truly isochromatic photographs are required, the time of exposure must be regulated to suit the degree of sensitiveness to red, which cannot safely be made greater than I have realized with my chlorophyl process.

INTERNAL TEMPERATURE OF THE SUN.—The various methods which have been proposed for determining the temperature of the sun have only referred to the superficial temperature, or that of a shallow depth in the photosphere, since the experiments have been limited to the light and heat which proceed from the photosphere. Some observers have supposed that the temperature does not exceed 1,500°C. (2,732°F.); others, Father Secchi among the number, suppose that the temperature exceeds 10,000,000°C. Hirn gives reasons for believing that the former figure is ten or fifteen times too small, while the latter is very much too great. He has devised an apparatus which he hopes will enable us at least to determine the lowest limit of admissible temperature, and which would probably already have given useful results, if his labors had not been unexpectedly interrupted. Since the light and heat at the surface of the photosphere emanate from solid particles, which are continually precipitated, and incandescent gas, the temperature of liquefaction and volatilization of those particles must be the superior limit of the superficial temperature. Judging from our knowledge of melting temperatures, all chemical combinations would be broken up, and all solid bodies would be vaporized at temperatures between 50,000° and 100,000°C. According to Faye's views, these solid particles, on penetrating toward the centre of the sun, must be liquefied and volatilized anew. The subjacent gaseous layers must therefore be at a far higher temperature than that of the upper surface. Applying the formula, $v = \sqrt{2gh}$ to the superficial jets of hydrogen by means of the estimated velocities which have been given by Lockyer, Young and others, he concludes that the internal temperature of the sun must be reckoned by millions of degrees.—*Comptes Rendus*, June 2, 1884. C.

FIRE HAZARDS IN TEXTILE MILLS.*

By C. John Hexamer.

When we consider that in the year 1883 about one hundred million dollars' worth of property was destroyed by fire throughout the United States, and, that if losses continue at the present rate, they will this year amount to one hundred and twenty-eight million dollars, we must admit that the study of fires and their causes is of intense interest and of the greatest practical value. For the sums just named are so great that the mind cannot conceive them; it is only by comparison that we can arrive at an approximate idea. Let us suppose a clerk to be counting off single dollar notes for the payment of these losses, and that he could count at the rapid rate of 100 in a minute; it would take him 2·43 years to complete his task, without a moment of sleep or rest. Or suppose I placed one dollar notes representing the amount of this annual fire waste in line lengthwise, edge to edge; it would form a line of greenbacks 7,893,333·3 feet long; or, to express it in miles, a strip 1,494·9 miles in length.

One of our technical papers, in moralizing on the annual fire loss over a year ago, truly said:

"All of this former huge amount of property has literally been blotted out of existence. Whether the losses were borne by the insurance companies or by individuals, the result is the complete extermination of just so much wealth which was created by human effort and ingenuity. The world is poorer by that amount than it would have been could these fires have been avoided.

"A person who considers these facts and figures thoughtfully must be impressed with the conviction that the existing means of preventing and extinguishing fires are either very inadequate or very greatly neglected.

"The whole matter will have to receive more consideration in the future than has hitherto been given to it. Civilized society, which leans so much upon human industry, cannot afford to permit vast quantities of the fruits of industry to be blotted out every year, when preventives are within reach."

As is the case in other investigations, it is most difficult to discover the origins—used here in its true sense, that is, causes—of fires. Before preventive measures against enemies of mankind can intelli-

* A lecture delivered before the Franklin Institute, Dec. 12, 1884.

gently be undertaken, be they epidemics or dangers of the elements, we must first know the causes which underlie the evil we wish to overcome. But the writer and observer on this subject labor under difficulties which the student of no other subject encounters to a like degree. The student of a new disease may note the symptoms of a great number of cases which he can diligently examine personally; we, on the other hand, receive our accounts from persons who observed what we most wish to know, while intensely excited and frightened, and only rarely do cases occur where any traces of the origin have been left, while it is exceedingly difficult to obtain information from employés, especially from watchmen, which would reflect on their judgment or honesty in performing their duty.

In order to lessen the number of fires, not so much better means for extinguishing, as better methods of preventing them, are required; and fires can only be prevented by a proper understanding of fire hazards by all classes. While means for extinguishing fires are daily approaching perfection, fire hazards are daily, through new inventions necessitating the employment of dangerous substances and processes, increased, and it is to the discovery of the hazards of every class of risks, and the invention of preventive means, to which the student of this subject must chiefly turn his attention. It is to the study of the fire hazards of a large class—textile mills—to which we turn our attention to-night.

One of the most trustworthy and complete tables, on the origins of fires in textile mills, is that kept by the Boston Manufacturers' Mutual Fire Insurance Company since October 1, 1850, which was furnished me complete up to January 1, 1884, through the kindness of Mr. C. J. H. Woodbury, their inspector. This table includes only establishments insured by that company—the best types of this class. It gives the causes and numbers of fires resulting from them as follows:

Causes.	Number of Fires.
Foreign substances in pickers	165
Friction	187
Spontaneous combustion through oils	115
Matches	52
Lighting apparatus	36
Sparks and defective chimneys	33
Incendiary	20
Spontaneous combustion of dyed cloth or yarn	26
Broken lanterns and lamps	17
Lightning	13

Causes.	Number of Fires.
Fireworks	7
Stoves	4
Pipes and cigars	4
Window glass acting as lens, concentrating the rays of the sun	3
Spontaneous combustion of bituminous coal	3
Electricity from belts	3
Electric light	25
Water inducing rapid oxidation of iron turnings, which set fire to the sawdust mixed with it (One of these was caused by a freshet.)	2
Hot irons	2
Cutting iron hoops on cotton bales with axes, sparks setting the cotton on fire	7
Heat from furnaces	5
Wood in contact with boiler setting	1
Result of boiler explosion	1

[One was caused by a man accidentally dropping an open penknife on a small bunch of cotton card waste, which burst into flames. After the fire was extinguished, a quartz pebble about one-eighth of an inch in diameter was found on the floor; the steel blade, striking this pebble, caused the spark which ignited the cotton.]

Causes.	Number of Fires.
Matches	12
Gas	7
Steam pipes	5
Mice	1
Hot flues	1
Sparks from emery wheel	1
Petroleum	1
Gasoline vapors	2
Breaking of shaft	1

Let us now turn from statistics to a closer inspection of the hazards, beginning with the raw stock in its progress through the mill.

RAW STOCK.

It may be stated, as an almost infallible rule, and I think the experience of underwriters will bear me out, that, other conditions being equal, the fire hazard varies inversely as the quality of raw stock, and therefore, also, inversely with the quality of the manufactured goods; that is, the poorer the grade of raw stock, the greater the fire hazard. It is absolutely necessary for a mill inspector to be conversant with the different kinds of raw stock, and he should be able to

make microscopic and chemical tests of the same, in order to determine the exact proportions of mixed stocks for himself, as the statements of the assured may be, and frequently are, incorrect. We will, further on, exhibit microscopic tests, on a large scale, by examining the different kinds of stock, as thrown on the screen by the projecting microscope.

In this section of the country the so-called "mixed" mills are found to a great extent, and these, on account of the greater fire hazard incident to them, are of special interest to us to-night. In its widest meaning, a "mixed mill" is one in which cotton and wool are spun (by which I include the previous processes of picking). The amount of cotton adulteration in the so-called woolen goods depends on the demands of the market for which the manufacturer is working; therefore, the proportions of raw stocks in many "mixed mills" are constantly changing from nearly all wool to nearly all cotton. By wool is meant the animal fibre of that name in any condition, including wool, shoddy, extract, waste, etc.

Cotton, as a rule, comes to the mill in a pure state; but, as in wool, there are different grades to be taken into account, not only from their commercial value, but from their fire hazard in being worked. The most objectionable grade is "damaged cotton," which has undergone partial destruction by fire, and which (in order to conceal the marks of charring) has been dyed with a dark color. Such cotton when run over the cards will create a great amount of fly, and is, therefore, as we shall presently see, much more dangerous than better grades. Dirty cotton has often been the cause of picker fires, and I am informed that bales are sometimes fraudulently loaded with sand and gravel to increase their weight.

As picker fires are generally due to stones, pieces of iron, etc., which, in coming in contact with the whipper, strike sparks, the value of clean, carefully inspected, cotton, from the fire point of view is self-evident, as is also the necessity of better methods and greater care on the part of Southern cotton growers in ginning, baling and transporting it. These desiderata, which could not be impressed upon the planters by way of the head and heart, have gradually influenced them by way of the purse, as they have found that it is commercially more advantageous to place their stock in the market in a clean condition, and they will, no doubt, very soon deliver it to their customers more free from hazardous foreign particles.

Cotton carding waste is sometimes used in low grade mixed mills,

and as it is very short fibred, being carded out in the white cotton mill, creates much fly and dirt in working it; and mills using it are very dirty and hazardous. Re-ginned cotton is another low grade, hazardous stock.

Wool is a much safer stock than cotton. Pure woolen mills are not frequently destroyed by causes directly or indirectly resulting from the stock; and pure worsted mills are among our best risks. It is through the adulteration of the wool that fire hazards are created, and in a direct proportion with the amount of adulteration.

Care should be exercised in wool-sorting rooms, as fires have been caused by the ignition of tar-marked fleeces laid on steam heating pipes to soften the tar used to mark the sheep. Mr. C. J. H. Woodbury suggests the following safe and efficient manner of softening the tar:

"A box about eight feet long, two feet wide and six inches deep, is provided with a bottom made of wire gauze of about one-half inch mesh. Under this box is a piece of iron pipe, with perforations upon the upper side, and connected with the steam supply. When this box is filled with fleeces, and the numerous jets of steam blown through them, they are softened much more rapidly than by warming in the usual manner around steam pipes or stoves."

Wool shoddy is a short fibred wool manufactured from rags. The picking of shoddy is very hazardous, and it is generally manufactured in extra mills (shoddy mills), and the stock or yarn sold to others. Where shoddy is made in a mixed mill it greatly increases the hazard, and the greatest care must be taken in the location and construction of the picker room. When used in large quantities in mixed mills it becomes a source of danger from the amount of dirt and fly made in carding. In picking the rags at the shoddy mill, much oil is frequently used on the stock. The kind of oil is of great importance, for if animal oils are used spontaneous combustion of the stock may ensue on being piled in quantity, and if some of the so-called wool oils be used, which are mixtures of animal oil and petroleum, the petroleum vapors arising from it during the process of manufacture may become dangerous. Yarns manufactured from shoddy picked with wool oil sometimes contain enough oil, even when dyed, to become dangerous on exposure to a high temperature in the dry house. The reason for this is that mineral oil will not readily saponify. An emulsion of lard oil and water with a little ammonia is the safest

substance to use on wool. Olive oil, which is frequently adulterated with cotton seed oil, should not be used.

Wool Extract is a shoddy manufactured from rags of a mixed stock, the cotton contained in it having been dissolved by dilute sulphuric acid. It has the objectionable features of shoddy.

Worsted waste, when clean from the drawing frames, is a very good stock, as it has been combed, and when not oily is cleaner and safer than raw wool. The so-called woolen noils, which is the soft waste taken from the wool on the combs, is also a good stock but not as good as pure wool.

Silk noils is the waste from the combs obtained in manufacturing spun silk yarns, is but seldom used, and is not specially hazardous.

In the lowest grades of mixed mills, where a cheap carpet yarn is made, hair, jute, flax, hemp, etc., are sometimes used in mixing. These stocks materially increase the hazard of the mill.

As before stated it is important for the insurance inspector and adjuster, not only to be competent to distinguish a good from a poor grade of wool, but also to be able to detect any cotton in woolen goods. This may, by practice, generally be detected at sight, or by the rough test of ignition. Animal fibres when singed give off a smell of burnt feathers, and when ignited in the flame of a candle are almost immediately extinguished, a carbonaceous residue being left; cotton and linen fibres continue to burn, do not give off the smell of burnt feathers, and do not leave a carbonaceous mass when extinguished. Where a little potash may be procured, the best and most reliable test is to place a piece of the goods in a solution of caustic potash; the wool being dissolved, the cotton remaining intact.

Another easily applicable test is that of nitric acid. On boiling tissues in this acid, silk will assume a light yellow, wool a dark yellow color, while flax, cotton and hemp will remain white. If the proportions of the different components are sought, a small piece of the goods is taken, carefully washed, to free it of all grease, and dried; this is then carefully weighed and boiled with caustic soda until the animal fibres are completely dissolved. The lye solution is then run through a filter, while the fibres remaining on the filter are thoroughly washed with water. The loss in weight of the fibres when dried will then give the amount of animal matter.

The best qualitative test is an examination with a good microscope. Under the microscope, as we will presently notice on the screen, cotton

has a flowing, twisted, band-like appearance; linen fibres appear as slender cylindrical reeds; wool has a thick circular stalk covered with scales; silk is slender, smooth, and shines brilliantly.

We cannot state too forcibly that the shapes and lengths of the raw stock are of the utmost importance in "Fire Technology," and that the causes of a great number of fires in "mixed mills" may be directly traced to the nature (physical and chemical) of the raw stock used.

Raw wool—although it does not burn readily—is a more unprofitable stock to insure than is generally supposed. There is but a poor salvage on wool. The keratin, the principal part of wool, when wet, ferments and decays, the wool thus becoming worthless. Although a stock of wool may not have been damaged by fire, it may still be a total loss, since the water poured upon it may have caused fermentation to set in. If speedily taken care of and dried, wool may be cured, although it seldom regains its original quality.

Let us now turn to the hazards of *Dyeing and Drying.*

The process may be generally divided into: first, the cleaning of yarn, warp, or raw stock; second, the dyeing proper; and third, drying. The first operation consists in boiling and scouring the material; this is performed in vats, the scouring being accomplished either by hand or automatically by scouring machines. This operation carries no special danger from fire with it, except where *oily* material is scoured, and then allowed to lie in heaps. When this is the case, we have one of the most favorable circumstances for spontaneous combustion.

The custom of some dyers of adding oil to the stock in the dye-tubs, to soften it, is a bad one. If properly dried, the oil is superfluous; if dried too hot, the presence of the oil in the stock materially increases the hazard of fire, from ignition of the damp, oily stock, subjected to the heat of the drying chest.

The process of dyeing creates no danger from fire; a hazard lies in the chemicals stored for the process. We find here unslaked lime (which, on getting damp, has caused fires); sulphuric acid; piles of logwood in the process of "curing," damp and liable to ignite spontaneously, etc. Although we have never heard of a fire caused by the spontaneous combustion of logwood, yet from what such eminent chemical technologists as Muspratt and Stohmann tell us of the nature of the process of "curing" logwood, it seems quite probable that fires may originate through its agency. Chlorate of potassium is also sometimes stored, concerning the hazards of which I will speak later.

After dyeing, the material is sometimes sized and (whether sized or unsized) dried; and it is here that fires in dye works chiefly occur. The danger of a dry house depends greatly on the material dried; for piece goods, warps or yarns, the danger is not so great as in the case of raw stock, and especially raw cotton. In the hot summer months, yarns, and, sometimes, even raw stocks are dried on "drying flats;" but, as a rule, they are dried in rooms heated by steam, furnaces, or by the natural heat of the boilers below. The steam pipes are arranged to run either along the floor, the wall, or, which I am sorry to say is seldom the case, along the main ceiling. The last arrangement is preferable, as in that case it will be impossible for the material to drop on the pipes. In this method of drying, the only requirements are that steam pipes rest on iron (as live steam pipes will ignite wood) and that the steam pipes are kept clean. The antiquated method of drying by furnaces is very objectionable, and has, in our country, been almost entirely superseded by the much safer process of steam drying. The last method, which is frequently used where drying rooms are situated over the boiler room, is the most economical process; and, when properly constructed, so that no yarn dust or fibres may fall within dangerous proximity of the boilers or boiler fire, has no special hazard connected with it. Special care should in this case be taken to have the boilers well enclosed by brickwork, and where this is not the case, a thick layer of sand should be spread on top of them, thus protecting them against falling particles.

The hazard of a yarn dry house varies with the nature of the yarns dried. It is safer to dry woolen and worsted than shoddy, cotton or jute yarns. Care must be taken to remove from the steam pipes under the floors all the fly and bits of yarn which may accumulate thereon. It is not advisable to have lights in dry rooms. Lights become especially hazardous when shoddy yarns, spun with low grade wool oil, or heavy black petroleum oils, are used. It is a well-known fact that oils of this kind cannot be saponified and washed out before dyeing, and must, therefore, be present in the yarns when the latter are dried. The heat of the dry rooms soon evaporates the lighter products of the petroleum, and in a short time the dry house is filled with very inflammable vapors, which would be readily ignited if brought into contact with an open light.

The custom of filling the dry house with yarn in the evening and turning on the steam in order to do the drying at night, when the rest

of the mill is not in operation, is a very bad one. The majority of our dry house fires occur towards morning, and, as a rule, on damp nights, when the moisture of the outside air prevents the escape of the hot air through the ventilators in the roof, and when the person in charge has turned on a full head of steam to overcome the increased moisture of the air in the dry house.

Ventilators in the roof of the yarn dry house which, if closed, open automatically when a dangerous temperature is reached in the dry room, should never be omitted.

In the dyeing of raw stock, especially of cotton, the conditions are changed, and even the best method is dangerous. This stuff will flash and spread in an instant, and before the hands employed have time to save themselves, everything is in flames. The apparatus for drying raw stock usually consists of a box closed at the top by a screen (over which the material is placed), a fan or blower, and the steam pipes for supplying heat. It is apparent that these may be put together and arranged in the following ways: Either the fan and pipes are in the box beneath the screen, or the pipes are outside and the fan under the screen, or the fan is outside and the pipes inside, or both are outside. The first arrangement is the poorest. In this case, the fan would draw the air from outside, force it over the steam pipes and into the stock; if a piece of cotton should fall on the pipes below it might ignite and impart the flame to the stock above. Besides, in all cases in which the fan is below the stock, the shaft and other working parts soon become covered with fuzz; this soaks up the oil with which such machinery must constantly be lubricated, and should at any time the journals, from some cause, as for want of oil, become hot, the greasy waste becomes ignited, and the flames ascend to the stock. Hot journals, on all kinds of machinery, are by no means seldom occurrences; the skillful inspector may frequently have noticed by a test, (not very æsthetic but practical), *i. e.*, spitting on the journals of revolving cards, etc., how the saliva instantly vaporized into a cloud of steam; and the impatient traveler may often have wondered "what are they stopping for," when the simple cause was a hot journal from an unoiled axle.

The second method of drying is better than the first, but is still subject to the latter objection; in this case, the steam pipes are above the stock, and the hot air is sucked through the stock by the fan (blower) beneath. The next is but the reverse of the foregoing, and is seldom employed.

The last is the best; in this case, the steam pipes are over the stock, while the fan sucks the hot air through the stock by a flue, which is connected with the box. A method often advised by some insurance men, but which I believe to be objectionable, is the following: The pipes are outside of the box, and on a lower level than the drying stock, the fan or blower being also outside and lower than the stock. The fan sucks the hot air from the pipes and blows it through a flue into the closed space under the stock. Now let us suppose that a thick layer of moist stock be laid on the screen, and observe the effect. The layer of moist stock will be almost impervious to a current of air, the hot air from the fan will be confined, cannot escape from the enclosed space below the screen, but the fan will continue pumping hot air into the box until very soon a dangerous temperature is reached.

There is also another mode of drying, but which, on account of the slowness of the process, is not much employed; that is, by cold air. The cold air dryers consist of a chest and fan or blower like the foregoing, but instead of using artificially heated air, they force through the stock, air from the room, at the same temperature as the surrounding atmosphere. These dryers are very safe; but, as before stated, on account of the slowness with which they work, are not much in use.

When steam coils are used much depends on the construction of the box enclosing the pipes. This box should be of iron. It is necessary to have an opening to the box to facilitate the cleaning of the steam pipes.

When air is sucked over the steam pipes, and then blown out through the stock, the air-opening in the chest containing the steam pipes, should, in all cases, be provided with a wire screen to prevent particles of stock from being sucked into the chest. Such stock, accumulating on the spaces between the hot pipes, will soon char, and frequently, when the fan is started after a short stoppage, the air blast will ignite this charring stock and carry it into the chest, causing ignition of the fly which will always be found in the chest.

Special care must be taken to provide an escape for hot air after it has passed through the stock, and the idea of providing no escape for the hot air from the enclosed space, in order to keep the heat in to do good and rapid drying, is erroneous. The air confined in the enclosed space, although hot, is so laden with moisture that, instead of helping the drying, it retards it. The hot, moist air must be got

rid of to insure rapid drying. Ventilation is absolutely necessary to rapid and safe drying. When ventilation is provided, dry, hot air will be constantly supplied to the stock, and the accumulation of hot air in an enclosed space will be prevented.

Systems so arranged that the fan takes the hot air from the enclosed space above the stock, and forces it over the steam pipes a second time, so that the same air is used over and over again, I consider not as safe as a system where the moist air is allowed to escape. The continued reheating of the air will soon raise its temperature to such a point that it will do the stock more harm than good. Dyed cotton dried in this way is likely to be very harsh to the touch, and very hard to work on the cards. The drying of raw wool is not by any means as dangerous as that of raw cotton. Nor is exhaust steam as hazardous as live steam.

The simplest and safest method of drying raw stock is, without doubt, the frame drying-flat, either on the roof of some low building, or on the ground. Stock dried by this method is uniformly dried. It does not show signs of baking, and works easily and softly on the cards, less oil being necessary, less fly being thrown off, and hence less hazard in the card room. The last is a very important factor of safety in a mill where dyed cotton (black or brown being the most hazardous) is used on woolen machinery. The system of drying by cold air is similar in its effect on the stock.

Where certain kinds of dyed cloth or yarn are dried, special care must be taken to prevent their spontaneous combustion; especially those in which the required shade of color has been produced by chemicals which absorb oxygen from the air, forming new compounds which produce the desired shade. The warmer the material comes from the drying cans, the less heat by slow combustion or oxidation is required for it to reach the ignition point, at which it starts into active combustion; or when it is tightly rolled or densely packed, the heat produced by the chemical action is not conducted away as readily as when it is exposed to the free circulation of the air, and, thus accumulating, soon reaches the ignition temperature of the mass. Fires of this nature have been caused by materials colored with browns made from catechu, cutch, gambier, or terra Japonica; iron buffs, indigo-blue, and cloth prepared with oil for Turkey red; and even, though but seldom, in logwood and iron blacks; and more frequently in blacks made from aniline and its salts. Spontaneous combustion can be prevented by

cooling the goods thoroughly as they come from the drying cans and submitting them to the action of the atmosphere on all sides. They should never be piled in quantity or put up in rolls until these precautions have been taken. Sized goods are not as apt to ignite spontaneously as those which are unsized; but such cases do happen and are especially apt to occur where much tallow has been used in the size, since animal fats are prone to ignite damp goods spontaneously. Fires have been caused by supposed well-cooled goods being piled over night. All goods received from drying cans before closing in the evening should be placed in a fireproof room for the night, which, in order to insure frequent inspections, should be one of the watchman's stations, and should be provided with automatic sprinklers and steam jets. When the steam supply pipes are properly hung (free from wood-work) and when proper ventilation is provided, there is no special hazard connected with a steam drying cylinder, either when drying piece goods or warps.

Especial care should be exercised in singeing. Goods should not be rolled or piled in quantity before being well cooled, and examined for glowing particles which may have remained in them.

Cloth, when woven of yarns spun with wool oil containing low test petroleum, gives off dangerous vapors, if subjected to a high temperature on the cylinders. I would, therefore, advise to have no artificial light in inclosed rooms where this operation is carried on.

Tentering machines, both horizontal and upright, extending through one or more floors, when properly put up are not very hazardous. The steam pipes must be frequently cleaned off to remove all fly which will accumulate on them, and when the tentering machine is in an inclosed room, ventilation is as necessary as in every other process of drying.

As before stated, chlorate of potassium is now much used in the preparation of aniline blacks, which are considerably used in print works. The danger of potassium chlorate may best be illustrated by a little experiment.

Before you, on this table, I have a mixture of chlorate of potassium and finely powdered sugar. If I add but a drop of sulphuric acid to it, the same will ignite with almost explosive violence.

[This experiment was performed.]

The reason for this, is, that the sulphuric acid abstracts the elements of water from the sugar, thereby generating sufficient heat to ignite the charred residuum, while the combustion is fed through the oxygen

contained in the chlorate of potassium, a substance which parts very readily with the oxygen it holds in chemical combination. The terrible explosions and fires which from time to time occur in candy manufacturies, manufacturing chlorate of potash drops, may now no longer be a mystery to you, as they have been, to many experts, consulted at the times of their occurrence.

PICKING.

After the raw stock has been properly dyed and dryed it must be willowed to remove the dirt; picked to reduce the knotted and tangled fibres, and mixed in proper proportions to facilitate the work on the cards.

The picking of the stock is justly considered the most hazardous operation in a mill.

The danger of the picker is the possible presence of foreign particles, such as stones, nails, etc., in the stock, coming in contact with the rapidly revolving cylinder of steel prongs, causing sparks and fires.

The hazard is proportionate to the inflammability of the stock. The willow, owing to its slow motion, and to the size of the teeth, which are frequently of wood, is not as hazardous. On the contrary, willowing the stock before picking it reduces the hazard materially, since most of the dust and foreign substances will be removed.

The mixing picker is the most hozardous, since the various grades of stock are passed through it at one time, the hazard being further increased by oiling the stock. Saponifying the oil reduces the hazard. This is done by adding either ammonia, potash or borax to the oil. Where the largest percentage of the mixing is cotton, a cotton-spreader is used, which is quite as hazardous, owing to the nature of the stock. Frequently a cotton-opener is used. This machine has caused so many fires that some managers have returned to the slower but safer process of "opening" the cotton by hand, or by a willow, before feeding it to the spreader.

In no case should open lights be permitted in picker rooms. Even inclosed lanterns will be a source of danger from the possible ignition of dust, which may accumulate on the top of the lamps, and which, igniting, may drop into a pile of loose stock. A light set in the wall provided with a heavy brass plate flush with the inside wall, and arranged to be lit from the outside only, is a very safe light for a

picker room. Incandescent electric lights when properly installed are excellent for picker house lighting.

Manufacturers frequently use their clean waste as a part of their "mixing." Where soft waste alone is used, no additional hazard is added to the picker room. Should, however, hard waste be used, a hard waste picker becomes necessary; this is one of the most hazardous pickers, equal in danger to the rag picker, which it resembles in construction. Careful managers, cognizant of this fact, do not pick their own hard waste, but send it out to be picked at shoddy mills.*

When a picker strikes fire, the burning stock will naturally be blown into the loose stock collected in the picker-box, hence the construction of this box is a very important point. In mills in the vicinity of Philadelphia, this box varies with the nature of the stock used. When pure wool only is used, the picker-box is often dispensed with. Where rags are picked, it is generally fire-proof. A substantial picker-box is preferable with any kind of stock. The best construction for the purpose is undoubtedly a brick chest with brick-arched ceiling with an iron-lined door at one side and an iron-lined slide to close the opening in front of the picker in case of an accident. An opening beside the door, which should be always closed when not used, is necessary for the passage of the air-blast. This opening can be readily made "fire-tight" by covering it with good strong wire-matting of close mesh. In place of this opening I would suggest a brick flue passing out of the roof of the picker-house, which can be protected from the rain, and will act as a chimney in case of a fire, being a natural outlet for smoke and flames without endangering the remainder of the picker-room. The only loss then will be the burning of the stock in the picker-box, at the time the picker strikes fire.

The flue from the picker to the dust-box, which should, in all cases be outside of the building (in some instances the dust-box is in a corner of the basement of the main mill) is best made of sheet-iron.

An undetected fire smoldering in the dust-box would soon find its way through a wooden spout into the picker-room after the picker is stopped. A light iron plate at the end of the metal spout so hung that it would be kept open by the air-blast when the picker is in operation and closed by its own weight when the picker is stopped, would be an efficient cut-off for a fire starting in the dust-box

* I am indebted to Mr. C. A. Hexamer for much valuable information in regard to pickers and picker-house construction, and have made copious use of his notes on the subject.—C. J. H.

One of the most objectionable features in the usual construction of the picker-house is the size of the edifice. In the majority of mills the picker-room is also used as a mixing-room. A trifling fire, when fed by a day's mixing and a week's stock in bales, will soon cause a heavy loss. The picker-room should be as small as possible, so that the temptation to make it a stock-room will be overcome. The mixing-room can be located in a separate room, separated from the picker-room by a brick wall and a good iron-lined door. Where the yard space is limited, the mixing-room may be built above the picker-room, An opening may be made in the fire-proof ceiling of the picker-room through which the stock can be lowered when ready for the picker. This opening in the ceiling should be provided with a fire-proof cover so arranged that it will always be closed when not in use. I would advise to have the stairway leading to the mixing-room in the second story built on the outside, so that there be no other opening in the ceiling, except the one closed by the fire-proof trap-door. If the brick flue from the picker-box is used, it must necessarily extend through the mixing room and out through the roof of the building. Steam pipes for heating the mixing-room are only safe when suspended from the ceiling. Many fires have occurred from spontaneous combustion of oiled stock piled against steam-pipes The danger from this source varies with the nature of the oil used on the stock.

When "phosphor-bronze" came into use some years ago, Mr. Edward Atkinson suggested the substitution of this alloy for iron whippers in the beater, as these would be less apt to produce sparks on coming in contact with foreign matter. He had an experimental picker manufactured, on one-half of the beater of which, ordinary whippers of Norway iron were used, and on the other half, those made of phosphor-bronze. Mr. Woodbury describes the results of experiments made with it as follows: "When the picker was in operation a number of pieces of iron were fed in, and a shower of sparks was emitted from the iron, but not from the 'phosphor-bronze' beaters; pieces of hard steel were substituted for the iron fed in, but with the same result. Phosphor-bronze whippers have been used in the same beater with Norway iron whippers for eighteen months; at the end of that time, the iron whippers had worn into the steel rods to which they were hinged, while there was no perceptible wear between the steel rod and the phosphor-bronze whippers. The working edges of the phosphor-bronze whippers were sharper than those of iron. The

results of extended investigations in the merits of this alloy show that it is superior to iron in safety, durability and efficiency."

CARDING.

The stock having been picked is now ready for the cards. The object in carding is the cleaning of the stock of dirt and foreign matter which may have remained after the picking, and to "card out" the short fibre of the stock, at the same time placing the various strands in parallel layers to facilitate the subsequent spinning. Cards are generally arranged in sets of three, and occasionally, of two and four.

A card consists of a large cylinder from three to four feet in diameter covered with card cloth (leather or rubber strips perforated by numerous steel wires of equal length), and of a number of smaller cylinders from six to eight inches in diameter. The smaller cylinders revolve in opposite directions to the large one; that known as the "fancy" revolving very rapidly. Where cotton or shoddy is used, the fancy should in all cases be provided with a metal cover, so that the short fibre carded out may be prevented as far as possible from flying about. The rapid revolution of the fancy makes it necessary to keep the journals of this cylinder well oiled. Carelessness in this respect has caused many card-room fires.

The hazard of the card-room consists chiefly in the accumulation of the particles of stock carded out, which, on account of their extreme lightness, fill the air of the room, and in settling, cover everything with a very inflammable substance usually known as "fly." As a general rule, the poorer the grade of stock, the greater the amount of fly created, hence the greater the hazard of the card-room. Wool alone, when run over the cards, does not create much fly. When cotton or shoddy is mixed with it, the amount of fly is greater; when cotton alone, especially dyed cotton, is run over woolen cards, the accumulation of fly, and hence the danger from fire, is greatest.

No doubt many of you have heard of the terrible explosions and fires which from time to time occur in flour mills. The reason for this, is, that when any organic substance, such as flour, is finely divided and mixed with air, it will, on coming in contact with a flame, be almost instantaneously ignited; the products of combustion being gases of many hundred times the volume formerly occupied by the dust, these, on expanding, create explosions.

If we enter a carding-room, in which cotton is worked over open

woolen cards, we find a condition of things almost analogous to that in a flour mill. The entire air of the room is filled with a finely divided organic substance which, under certain circumstances is even more explosive and liable to ignite than finely divided flour. The only reason that we have not the severe explosions, for we frequently have the almost instantaneous fires, that we have in flour mills, is that the card-rooms are, as a rule, large, and the gases caused by the almost instantaneous ignition find means of exit without causing explosions —while in flour mills we have numerous enclosed spaces, such as smutters, mill boxes, elevator-boots, etc.

A substance becomes the more inflammable, the greater its affinity for oxygen; thus the combustibility of a fibre increases directly with the avidity it has for the oxygen of the air. If, therefore, in the processes of dyeing, the property of uniting readily with oxygen has been imparted to the fibre, the finely divided fibres, commonly called "fly," are more apt to ignite. It is for this reason that fibres dyed with certain chemicals which absorb oxygen are much more hazardous than the ordinary raw stock. Cotton, the purest form of cellulose in nature, after treatment with chemicals required for the production of some colors, undergoes a change of state, in which it resembles guncotton.

You will, by this time, have perceived the reason why the so-called mixed mills are so much more hazardous than the ordinary pure stock mills; the reason being that in the former, cotton, and, frequently, dyed cotton, is worked over open woolen cards, creating a vast amount of fine, extremely combustible and explosive cotton fly.

In order to test the explosiveness of different dusts, I have constructed an explosion apparatus.

The questions to be determined for every kind of dust are at what degree of humidity it will cease to explode, how finely divided each kind of dust must be in order to explode; and the determination of the temperature at the time of explosion. [A large drawing of the apparatus was shown.]

The apparatus consists of an ordinary kitchen boiler (such as is used for heating water), with its top taken off. This top may be closed by a ring over which tissue paper has been pasted, and the ring is tightly screwed on as shown in the drawing. In the interior you will perceive two hooks, one being for the reception of a thermometer by which the temperature of the atmosphere in the interior may be obtained before exploding the dust, and the other for a hygrometer, by which

the humidity of the contained air is determined. In the bottom of the apparatus a gas pipe is inserted, the jet being lighted (in order to secure greater safety) by electricity from a distance. On the upper end a funnel with a blower is attached, by means of which the finely-divided dust may be blown in. In order that I may not be dependent on the surrounding atmosphere for the temperature and the humidity of the contained air, a small boiler is connected with the apparatus, by means of which steam may be blown into the interior, and thereby any degree of humidity produced that is desired; while the temperature may be regulated by the gas jet burning in the bottom.

The manner of using the apparatus is as follows: After the temperature and humidity of the enclosed air have been determined, the thermometer and hygrometer are removed, the cap with the tissue paper cover is tightly screwed on, and the dust blown in. When a short time has been allowed the dust to mingle with the contained air, the gas jet is lighted by means of electricity, and the explosion occurs.

I am now engaged in making numerous experiments with various kinds of organic dusts, which are produced in different technical occupations; and will publish the results of my experiments, when they are completed.

SPINNING.

From the cards, the stock is taken to the spinning frames, and this department is one of the most prolific sources of fires caused by friction, especially in the mule heads, which should be kept thoroughly clean and lubricated. The ends of the carriages next to the head should be well closed, with an opening just large enough for the drum cords. When fires originate in mule heads, the flame is transmitted throughout the machine with almost instantaneous velocity, unless the carriage is kept very clean and clear of oily waste.

OILS.

Statistics of fires among New England mills have shown that 37 per cent. of fire losses are caused by spontaneous combustion, and hot journals from friction caused by bad oils. A good lubricating oil should be neither acid nor strongly alkaline; nor should it, through variations in temperature, become acid or alkaline. Most vegetable and animal oils, when they are exposed to high temperatures, such as that of superheated steam, are decomposed, and acids are set free; as they

are composed of stearic, oleic and palmitic acids combined with glycerine. These free acids corrode the surface of the metals, making them rough, and forming compounds which are the very opposite of lubricants. Their use, therefore, for journal-boxes, in hot weather, or where they become heated, is to be deprecated, for at high temperatures they combine with the oxygen of the air and decomposition results.

A mineral oil never becomes acid from decomposition, and will not corrode the metals to which it is applied. When these oils are mixed with glycerine, they form a very good lubricant. The great danger in buying mineral oils is that large quantities are annually put into the market far below the necessary flash test. These oils should be prepared by fractional distilation at a temperature not below 500° F. When mineral lubricants with a low flash test are used, they are exceedingly dangerous, as, on becoming heated in the journal, the volatile parts go off as vapors, making it dangerous to examine a journal or any other part with an open light. In order that a mineral oil should be a good lubricant, it should not flash under 300° F.; should not give off more than 5 per cent. of volatile matter at 140° F. in twelve hours; should be free from grit; and should contain no free acids or alkalies.

To determine the flash test accurately, an instrument too complicated for the use of the ordinary manufacturer is required; but he may, for his purpose, approximately determine the same by pouring the oil in a flat dish, which is placed on a plate containing dry sand, to which heat is applied (so as not to apply the heat to the oil directly), thus causing a gradual heating of the oil. A thermometer is then inserted some distance from the bottom of the dish, and the rise of the temperature noted. A lighted taper is then moved over the surface of the oil, care being taken not to touch it. If the vapors given off by the oil flash below 300° F., the oil is to be condemned as unfit to be used as a lubricant.

To determine the amount of volatile matter in an oil, the sample must be carefully weighed on a fine balance, and then exposed to a temperature of 140° F. for ten or twelve hours; then, after cooling, reweighed. The loss will represent the amount of volatile matter given off in that time. If the loss be more than five per cent. the oil should not be used.

In order to determine the amount of solid foreign matter (such as grit) in oil, a sample very near the bottom of the barrel (as the greater

gravity of the solid material will cause it to settle on the bottom) should be taken and placed between two clean glass plates and then rapidly rubbed together, when the grit will at once be detected.

Acids or alkalies in oil may readily be detected by means of litmus paper. If blue litmus paper is dipped into an oil containing acids, it will be colored red, while red litmus paper is turned blue when dipped into an oil containing alkalies. Any oil giving an acid or strong alkaline reaction should be condemned.

Mineral oils sometimes give an acid reaction, not from any decomposition of the compound, but from the sulphuric acid used in the processes of manufacturing it, which has been incompletely neutralized with caustic soda. If the amount of soda has been too small, an excess of acid remains; while in the presence of an excess of soda, a residual amount of soda will remain, which also has a bad influence on the metal bearings.

A test for sulphuric acid can readily be made by mixing a sample of the oil with water, and after shaking it well, allowing it to stand until the oil separates from the water, which is then poured off. On account of its hydroscopic properties the sulphuric acid will have united with the water. If now a solution of a barium compound be added to the water, a white precipitate of sulphate of barium will at once be caused, if sulphuric acid be present in the oil. In order to make the test sure, as there are other acids which throw down a white precipitate, the precipitate must be treated with strong nitric or hydrochloric acid, and if it remains unchanged, sulphuric acid is contained in the oil.

If the litmus paper shows the presence of alkalies, these may be tested by treating the oil with water, as before described, then evaporating the solution to dryness, and placing the residue in the colorless flame of a Bunsen burner. Sodium will give an intensely yellow flame, if potassium be present a beautiful violet flame will be produced.

Adulterations of animal oil or mineral oil may be detected by adding concentrated sulphuric acid, when the animal oil will be charred, forming black rings in the sample. Vegetable or animal oils can also be detected by adding an alkali to the sample, thus causing these to saponify; as mineral oils have not the property of saponification. Oils are frequently adulterated with cotton-seed oil, which is prone to ignite waste spontaneously.

SPONTANEOUS COMBUSTION.

Numerous fires are caused by what is commonly known as spontaneous combustion. Spontaneous combustion of oily rags or waste is caused by a rapid absorption of oxygen from the air, oils which have a great avidity for oxygen being the chief causes. By a number of experiments, it has been shown that when vegetable or animal oils contain one-third, or over, mineral oil, they will not ignite waste impregnated with them, spontaneously.

I have not time enough this evening to go into a lengthy discussion of spontaneous combustion and its causes, but must refer you to my work on "Spontaneous Combustion," which will shortly appear, in which this branch of the subject is treated in detail. I will merely give you the experiments of Dr. James Young, which are before you.

TEMPERATURE OF CHAMBER FROM 130° F. TO 170° F.

Boiled linseed oil on cotton ignited in				1½	hours.
Raw	"	"	"	4	"
Lard	"	"	"	4	"
Colza	"	"	"	6	"
Olive	"	"	"	5	"

Seal oil and mineral oil, equal parts, on cotton, would not ignite.

TEMPERATURE OF CHAMBER FROM 180° F. TO 200° F.

Colza oil on wool ignited in		6	hours.
Olive oil on cotton	"	2	"
Olive oil on wool	"	7	"
Seal oil on wool	"	3	"
Whale oil on jute	"	9	"
Whale oil on cotton	"	3	"
Cotton-seed oil on wool	"	5½	"

The following were not ignited by twenty-four hours' exposure in the hot-air chamber:

Olive oil and mineral oil, equal parts, on cotton.
Colza oil and 20 per cent. mineral oil, on wool.
Seal and mineral oil, equal parts, on wool.
Whale and mineral oil, equal parts, on jute.
Cotton-seed oil and 20 per cent. mineral oil, on wool.

The following table exhibits the results of the experiments of J. J. Coleman:

	Entered into combustion after	At a temperature of
Cotton waste saturated with whale oil	3 hours.	165° C.
Cotton waste saturated with olive oil	4 "	177° C.
Olive oil and 20 per cent. mineral oil	8 "	177° C.
Mineral and olive oil, equal parts, no change after lapse of 26 hours, after 12 hours, temperature 95° C		
Wool waste and seal oil	3 "	194° C.
Wool waste and whale oil	3 "	188° C.
Wool waste and cotton-seed oil	5 "	178° C.
Wool waste and olive oil	7 "	177° C.
Wool waste and refined rape oil	6 "	177° C.
Wool waste and crude rape oil	8 "	163° C.
Wool waste and cotton-seed oil with 20 per cent. mineral oil; seal and mineral oil, equal parts; olive and mineral oils, equal parts, unaltered after lapse of 26 hours.		
Jute waste with whale oil	8 "	180° C.
Jute waste with whale oil and mineral oil, equal parts, unchanged after 26 hours.		

I am at present engaged with a number of experiments on spontaneous combustion with very carefully constructed apparatus, which, I hope will prove more accurate than those formerly made with cruder apparatus.

[A large drawing of the apparatus was shown.]

The figure before you illustrates the device. Inside of the upper half of a strong metallic box, divided in two by means of a metallic partition, is placed a wire cage containing the material saturated with the oil to be experimented with. The wire box is surrounded by an air space on all sides, being, for this purpose, placed on legs, so as not to be in direct contact with the metallic surface of the partition. The lower half of the subdivided box is connected with a small boiler in which steam is generated (by means of a Bunsen burner), and the steam entering the lower half of the box produces an equalized temperature in the upper division, while the material to be experimented with, is surrounded and submitted to the action of the air on all sides. A thermometer is inserted in the upper partition, by means of which the exact temperature in it may be noted. In order to increase the temperature to any desired degree, the steam which passes through a strong pipe from the boiler to the lower half of the box, may, in its

passage be heated to any desired temperature by applying a Bunsen burner to the pipe. In order that the rise of temperature in the mass before ignition may be noted, and also the exact time when ignition has set in, a number of thermostats, set for various temperatures, are placed in the mass experimented with. These, as well as a conductor with a fusible solder link in it, form electric circuits, and are connected with electric clocks. As soon as the temperature corresponding to each thermostat is reached, the contact is broken, the clock stopped, and the interval between starting the experiment and this time can be noted, while the time of ignition of the mass is indicated by the stopping of the clock placed in the circuit containing the fusible solder joint. That the amount of humidity (which plays an important role in the spontaneous ignition of waste) may be varied, a small steam boiler, like the one described in the explosion apparatus, is connected with the upper chamber, and any desired quantity of steam may be blown into the same, and the humidity of the contained air altered at will.

I have spoken of the importance of the microscope in relation to testing textile processes, and will now show you a series of microscopic slides thrown on the screen, greatly enlarged. Fine fibres, which ordinarily are hardly visible to the naked eye, will be seen projected on the screen four, and on the rear wall, eighteen inches in diameter. This is accomplished by means of Mr. Holman's excellent lantern, a one-tenth immersion lens being used (the object and the lens being both immersed in glycerine); the entire light of a large electric arc lamp being concentrated through a small aperture not much larger than the head of a pin, and projected on the screen.

The following fibres were then shown on the screen:

1. Cotton fibre fresh from bale.
2. Cotton from bale dyed with aniline black.
3. White carded on flat cards.
4. Gray 1 and 2 mixed, carded on flat cards.
5. Gray 1 and 2 mixed, carded on worker and stripper cards.
6. White (3) spun in three thread loosely.
7. No. 3 dyed light-blue spun in 3 loosely.
8. No. 3 dyed deep-blue spun in 3 loosely.
9. No. 3 badly dyed red, spun in 3 loosely.
10. Sea Island spun white in six cord, tight.
11. Sea Island deep-blue in six cord, tight.

12. Sea Island badly dyed red in six cord, tight.
13. Flax (raw fibre).
14. Jute (fibre).
15. Sheep's wool donskoi. (The scale-like structure was shown highly magnified with great clearness.)
16. Silk fibre reeled and dyed.
17. Fabric (silk-poplin) wool, silk and linen.
18. Fabric (all-silk).
19. Wool waste.
20. Extract of wool.
21. Silk noils.

ELEMENTS OF SOLAR ROTATION.—Spörer has tested his own observations by means of the result which was pointed out by Faye, that the proper movement of the sun spots in latitude can be represented by a sinusoid. The direction of the spots in the equatorial regions mainly toward the equator, while the movement toward the poles predominates in high latitudes, might be explained by supposing that the spots in the former case were on the descending branch, and in the latter on the ascending branch of the curve. This would require, however, that the spots should be hidden, for some unknown reason, behind the sun's disc when they were on the other branches of the curve. He gives various other tests, under various hypotheses, each of which involves an indeterminate condition. There was, however, one spot which remained visible during four consecutive rotations of the sun, and for which he was able completely to observe the sinusoid of the variations in latitude in all the periods. He was able to determine the sinusoid, independently of the node and of the declination, by means of the intersection of the curves with the parallels of latitude which he obtained for the first and second, as well as for the second and third periods. The sinusoid thus deduced for the three periods also satisfied the observations of the fourth.—*Comptes Rendus*, May 19, 1884.

[Faye's remarks upon the above communication, as well as Lamey's explanation of the conservation of solar energy (*C. R.*, May 26, 1884), corroborate Chase's theory that the fundamental velocity of solar rotation, as well as of rotation at the centre of all other stellar systems, is always dependent upon the velocity of æthereal undulation.] C.

OPTICAL EXPERIMENT.—Take a piece of paper or cardboard, pierce a very small hole with the point of a pin, and hold it with the left hand at about 18 inches from one of the eyes. Stand so as to have the hole illuminated by daylight or lamplight, then introduce with the right hand the head of a pin between your eye and the hole. The shadow will be thrown upon the retina in such a way that the pin will appear to be reversed.—*Les Mondes*, Jan. 12, 1884. C.

ECONOMY IN THE USE OF HIGH PRESSURE STEAM.*

By William Barnet Le Van.

The importance of the use of *high pressure steam* cannot be too constantly urged upon engineers and manufacturers, and that the employment of low pressure steam in engines is extremely wasteful; yet, clear as this is or should be to all intelligent engineers and steam users, they do not recognize the truth. One may often hear an engineer boasting, "I have got an extremely good engine; its 'boss,' she will drive the whole load with forty pounds of steam," never reflecting that, when he is using steam at only forty pounds above atmospheric pressure, in a non-condensing (high pressure) engine, one-third of the whole of the fuel is consumed in getting the steam up to the atmospheric pressure; while, if he were to use the steam at one hundred and twenty-five pounds to the square inch, only one-ninth of the fuel would be so wasted.

When steam is used in non-condensing engines, at low pressure, the loss is great, owing to the pressure of the atmosphere (14·7 pounds), being a greater percentage if a low pressure is used than a high pressure.

The loss for different piston pressures is as follows:

Atmospheric pressure.	Steam pressure in boiler.	Total pressure on engine piston.	Percentage of loss.
15	5	20	¾ or 75· per cent.
15	10	25	⅗ or 60· "
15	15	30	½ or 50· "
15	20	35	⅘ or 44·4 "
15	25	40	⅜ or 37·5 "
15	30	45	⅓ or 33·3 "
15	35	50	⅗ or 30· "
15	45	60	¼ or 25· "
15	60	75	⅕ or 20· "
15	75	90	⅙ or 16·6 "
15	90	105	⅐ or 14·2 "
15	100	115	⅛ or 12·5 "
15	125	140	⅑ or 11·1 "

* Read at the Stated Meeting of the Franklin Institute, February 18, 1885.

This has reference only to the pressure on the piston in the cylinder of the engine, and does not refer to the boiler pressure, as indicated by the steam gauge.

It has been proven, both in practice and theory, that the *greater* the *difference* between the *steam pressure on the piston* and the *resisting forces* of the *condenser, or atmosphere*, the *higher* will be the mechanical efficacy of the steam; and hence the necessity of employing *high pressure* steam, in order to obtain the fullest effect of *expansion*.

It is a well-known fact that the secret of economy in running steam engines lies in the adoption of the highest practicable pressure of steam, thorough jacketing about the cylinders, steam pipes and steam chests, the earliest cut-off at which the engine will do its work, and as perfect condensation of steam as possible after the steam has done that work.

No engine can run economically at a high grade of expansion, except it be fitted with a condenser; for the greatest economy of expansive working lies in expanding below the pressure of the atmosphere. The highest attainable economy would be in expaning down to a perfect vacuum.

In the boiler, the test of economy is the quantity of water evaporated into dry steam for each pound of coal burned. If this quantity be above eight pounds, the boiler is economical, and *ten pounds* is the maximum realized in the best boilers. Apart from the evaporative power of the boiler, its cost, durability and convenience for repairs are important considerations, and demand due attention.

In order that the comparative values of high-pressure steam and low-pressure steam may be made quite clear, I exhibit on the screen a theoretical diagram, in heavy black lines, which is intended to show the ultimate practical amount of work to be obtained from a given quantity of water converted into steam at different pressures, and it is based on the fact that in any two boilers, steaming at different pressures, the same amount of fuel will practically evaporate the same weight of water. The steam is expanded down to seven pounds above zero, ($2\frac{7}{10}$) two and seven-tenths pounds to be deducted for back pressure.

The figures on the left give the pressure in pounds per square inch, the lower figures represent inches of stroke.

The explanation is as follows: When using steam at atmospheric pressure, and expanding it down to seven pounds above zero, the cut-off to effect this will be 0·5, or five-tenths of the stroke; the steam will

be also expanded 0·5, or half of the stroke; the mean pressure will be 11·96 pounds, and the mean effective pressure 9·26 pounds, and at any other pressure as per following table:

Pressure in pounds per square inch.	Steam cut-off at hundredth of the stroke.	Rate of expansion.	Mean pressure in pounds per square inch.	Mean effective pressure per square inch.
Atmospheric	0·50	0·50	11·96	9·26
10	0·29	0·71	15·96	13·26
20	0·20	0·80	18·38	15·68
30	0·16	0·84	20·17	17·47
40	0·13	0·87	21·61	18·91
50	0·11	0·89	22·70	20·00
60	0·095	0·905	23·70	21·00
70	0·085	0·915	24·50	21·80
80	0·077	0·923	25·40	22·70
90	0·070	0·93	26·10	23·40
100	0·065	0·935	26·70	24·00
110	0·057	0·943	27·20	24·50
120	0·050	0·95	27·70	25·00
130	0·047	0·953	28·00	25·00
140	0·045	0·955	29·15	26·45
150	0·0425	0·9575	29·70	27·00
160	0·040	0·96	30·20	27·50
170	0·0375	0·9625	30·80	28·10
180	0·037	0·963	31·20	28·50
190	0·035	0·965	31·70	29·00
200	0·034	0·966	31·90	29·20

The last column gives the comparative horse-power; for example, if an engine, running with a steam pressure of fifty pounds per square inch, expanding down to its lowest practical limit, namely, seven pounds above zero, will develop twenty horse-power, the same engine, running with steam at one hundred and twenty pounds, and expanding down to seven pounds above zero, would develop twenty-five horse-power with the same consumption of fuel; or, if the horse-power remain the same, the consumption of fuel will be reduced in the ratio of 20 to 25, or *twenty per cent.* in effect.

This is well illustrated in our best locomotive practice where high pressures are used. Take the case of Locomotive No. 10, Class "K,"

Pennsylvania Railroad; this locomotive develops on an average 700 horse-power for the two hours' run between Philadelphia and Jersey City with an average consumption of 5,775 pounds of coal, or 4·12 pounds per hour per horse-power.

[The speaker here exhibited on the screen, with the aid of the lantern, a *fac simile* of a diagram, showing the action of steam in an advanced type of automatic condensing engine using high pressure steam, developing about *ninety per cent.* of the theoretical diagram.]

IMPROVED HORIZONTAL FLUE BOILER FOR HIGH PRESSURE STEAM.

It therefore, appears, that by the use of steam at high pressures, a steam engine will perform the same amount of work with less steam and fuel.

All engineers agree that the disturbance in the boiler will be much less at a high than at a low pressure, and the escaping steam will therefore carry more water along with it at low pressure. For this reason the use of high steam pressures is desirable.

These boilers present special and exceptional advantages for producing high pressure steam, in the following particulars, the importance of all of which will be obvious to the user, viz., strength and simplicity, freedom from foaming, quick steaming capacity, making dry steam, large releasing surface and steam room, rapid circulation, nearly perfect combustion, safety and economy.

CONSTRUCTION.

The shell is made telescopic and is formed of three single plates, of best homogeneous steel, three-eight ($\frac{3}{8}$) inch thick, 53$\frac{1}{4}$, 54 and 54$\frac{3}{4}$ inches internal diameter, and sixteen (16) feet long. The transverse joints are single riveted, two and one-half (2$\frac{1}{2}$) inches pitch. Longitudinal seams, double-riveted butt joints with inside and outside covering strips, with pitch of rivets three and one-half (3$\frac{1}{2}$) inches. All the longitudinal joints are placed above the water line. Heads half ($\frac{1}{2}$) inch thick steel, well stayed with tee iron and braced to centre shell plate, thus releasing transverse joints from strain. The shell contains thirty-two (32) flues four (4) inches external diameter, well expanded into and beaded over end plates, and so arranged that there is a clear space vertically of three (3) inches between them in the centre of the boiler, and three (3) inches space between shell and flues, to allow a free circulation of the water.

The steam drum is twenty-four (24) inches diameter, eight (8) feet

long, five-sixteenth ($\frac{5}{16}$) inch thick, and connected to main shell by one twelve (12) inch neck, and so arranged that it is placed horizontal, while the main shell "rakes" six (6) inches in sixteen (16) feet. All the rivet holes are punched three thirty-seconds ($\frac{3}{32}$) inch less in diameter than the rivet, and when all the plates are brought well together in place by temporary bolts, the holes are reamed fair to receive the rivets, and countersunk slightly so as to form a fillet to rivet heads, the countersinking being done by a steel pin so that there is no reduction in value of the plates as would be the case if cut away by a reamer.

STRENGTH OF MATERIAL.

All the shell plates exceed 58,000 pounds per square inch tensile strength and have an elongation of at least twenty-eight per cent.

A safe working pressure of one hundred and fifty pounds per square inch above the atmosphere is allowed under ordinance of the city of Philadelphia as per formula of Boiler Commission, to wit:

Formula A.

Percentage of the strength of the sheet as compared to the strength of the solid part of the same sheet,

$$\% = \frac{s - d}{s} = \frac{3{\cdot}5 - 0{\cdot}81}{3{\cdot}5} = 0{\cdot}75 \text{ per cent. of seam.}$$

Formula B.

Percentage of the strength of the rivet in the seam as compared to the strength of the solid part of the plate or sheet,

$$\% = \frac{an}{st} = \frac{0{\cdot}5184 \times 2}{3{\cdot}5 \times 0{\cdot}375} = 0{\cdot}77 \text{ per cent of rivet.}$$

Formula C.

Pressure per square inch at which the safety-valve may be set,

$$p = \frac{Tt\,\%}{rf} = \frac{58000 \times 0.375 \times 0{\cdot}75}{27 \times 4} = 154 \text{ pounds per sq. inch.}$$

s = Space or pitch of rivets in inches.
d = Diameter of rivets in inches.
t = Thickness of the plate in inches.
a = Area of rivet holes in square inches.
n = Number of double rows of rivets in the seam.

f = Factor of safety. In this case four is allowed.

$\%$ = Lowest percentage of plate or rivet per formula A or B.

p = Pounds per square inch above the atmosphere, the safe working pressure.

T = Tensile strength of the plate or value in pounds per square inch of section of plate or sheet.

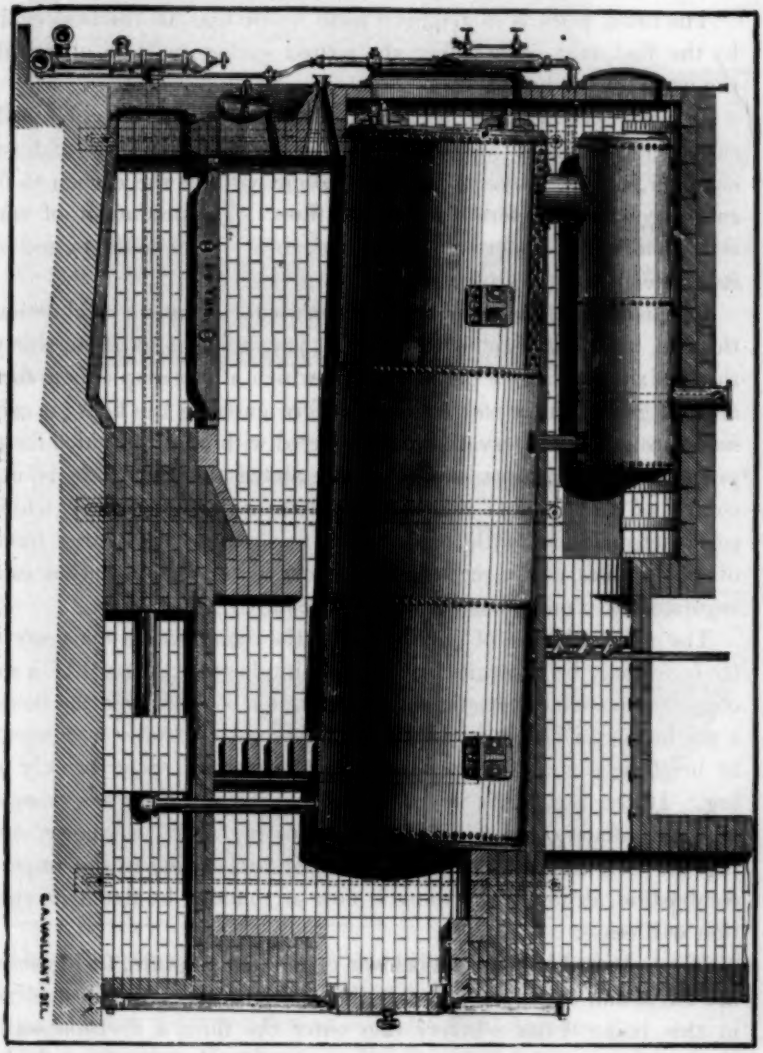

FIG. 1.—Vertical Section of Boiler.

BRICK SETTINGS.

The plan of brick settings shows a large *economy of fuel*, with increased capacity of *steam power*. The arrangement of furnace is such that the heat of the fire is distributed over the whole lower part of the shell. This latter is the result of the arrangement of the system of combustion employed.

The brick work is so arranged as to insure that all the heat evolved by the fuel, and passed over the wetted surface, will be absorbed by the water in the boiler.

It is well known that perfect combustion can only be obtained by supplying sufficient air under the grates and in the combustion chamber, so that the oxygen may combine with all the carbon to form carbonic acid gas before reaching the flues. The production of smoke is an evidence of imperfect combustion, since smoke contains, and owes its existence to, unburnt carbon.

In this boiler furnace provision is made for complete combustion of the fuel before it reaches the flues. The boiler is set from thirty to thirty-six inches above the fire grates, which allows ample room for the air and gases to mix and combine before entering the flues (as can be seen through the observation hole, covered with mica, provided for that purpose). The proper supply of air above the fire grate is under control of the fireman; it is introduced through the fire door, which is constructed hollow, with inside lining perforated with a large number of small holes, and a register on the outside of the door that can be regulated to admit the exact quantity required.

The evil influence of leaving too little room *between the grate and the boiler* may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a gas burner, a little above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered *into the middle of the flame* this will immediately lose its brightness, becoming dull and smoky, covering the bottom of the capsule with soot, and owing to the imperfect combustion, although the water is now surrounded by flame, its ebullition will cease.

It is well established, that below a certain temperature, fuel gases will not burn, and therefore to insure the consumption of all the fuel gases in this boiler furnace before they enter the flues, a division wall or septum separates the fire grate and combustion chamber from the back

end of the boiler where the gases enter the flues. This wall, extends up to and completely around the boiler, thus preventing any of the fuel gases from escaping except through the perforations in the wall.

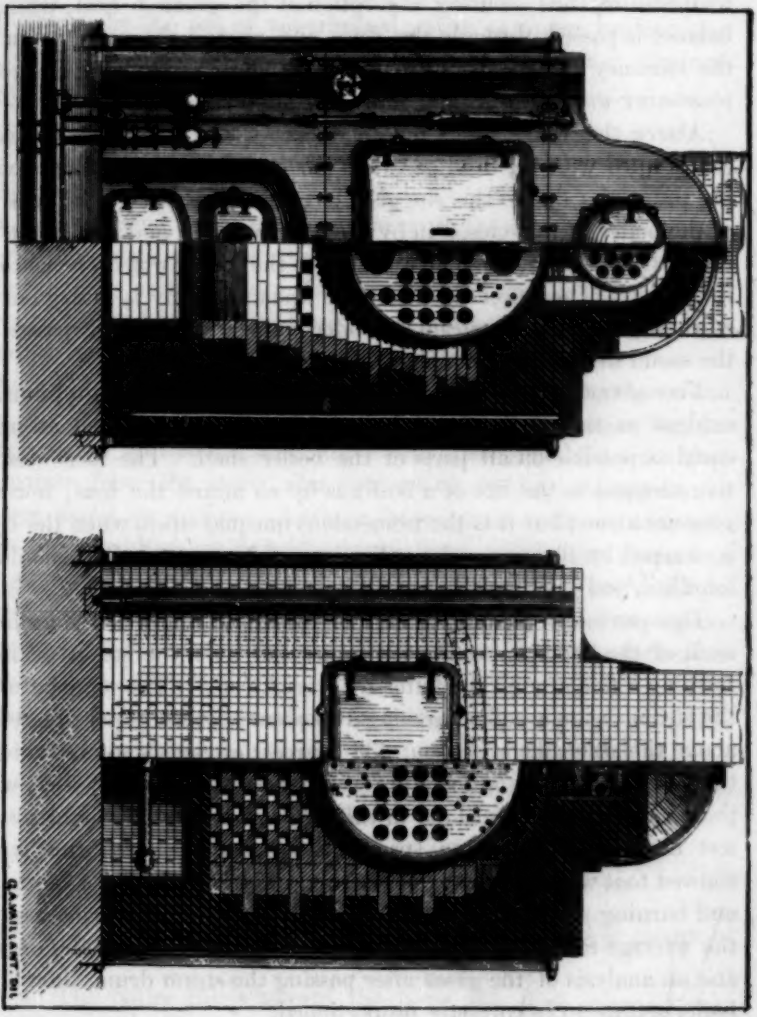

FIG. 2.—Half section of front and through fire-box.

Half section of back and rear combustion chamber.

The fuel gases are thus compelled to come in contact with the highly heated fire brick forming the division wall and form flame which cannot exist below a temperature of eight hundred degrees.

The combustion chamber over the fire grate is continued up to the

water line, having a space between the boiler and combustion chamber walls of four inches; thereby allowing the products of combustion to impinge on all the *wetted* surface before entering the flues at its highest temperature, thus securing absorption at the greatest heat, while the balance is passed through the flues and around the steam drum into the chimney at a temperature which renders the use of a separate *economizer unnecessary.*

Above the water line a hot-air jacket space is formed, which becomes filled with the dead gases at a moderate heat and without oxidizing properties due to the sluggish circulation caused by the back end of the boiler being closed in by the division wall, and the front end closed from the water line upwards to the flue formed on the top of the boiler. The effect of this plan upon economy is to dry out any entrained water in the steam of boiler proper, and when it passes into the steam drum to cause a slight degree of superheating.

The advantage of this mode of setting as to durability, must be evident as this is promoted by a temperature maintained as nearly equal as possible on all parts of the boiler shell. The most destructive element to the life of a boiler is by no means the heat, nor is it pressure alone; but it is the tremendous unequal strain when the boiler is warped by the unequal application of heat. A boiler should be kept hot, and kept equally hot all over.

The products of combustion after passing through the flues in the shell of the boiler are conducted under and over the steam drum by forming a flue around the latter with brickwork. The temperature of the steam inside a boiler carrying 100 pounds pressure per square inch above the atmosphere, is about 338 degrees; obviously any reduction of the gases below that temperature would actually *cool* the boiler, while those gases would be still *hot* in the ordinary sense, but would act as a wet blanket on the steam space. But experience with this setting showed that with a chimney of six square feet of area and 44 feet high and burning *pea* coal, the temperature *never* fell below 350 degrees, and the average for over a continuous run of two months was 400 degrees, and an analysis of the gases after passing the steam drum, showed the boiler setting to be correctly proportioned.

SUPERHEATED STEAM.

For some time past engineers have abandoned superheating, although its value is well understood, but this has been from the want

of proper packing and lubricants. In the present advanced state of the arts the above objection to its use can now be overcome.

The advantages to be gained in the use of superheated steam cannot be over-estimated. The use of wet steam augments cylinder condensation, whereas by the use of superheated steam cylinder condensation will be reduced to a minimum, from the fact that the latter conducts heat very slowly.

PRIMING.

The worst defect a boiler can have is a disposition to prime; in other words to send water as well as steam to the engine. Whether a boiler primes much or little, the defect is serious. Priming is in conventional terms nothing more than a boiling over. The steam as it is generated, instead of escaping freely from the water, is entangled with it, and carries over in its grasp a certain portion of the fluid.

The Le Van improved boiler overcomes priming by having a steam space, the latter being enveloped in the hot gases at a temperature exceeding that of the steam. The large steam space gives the water time to separate from the steam, also preventing sudden changes in the pressure above its surface. Again, a large water surface acts beneficially by providing an extensive area from which the steam can disengage itself quickly without carrying up much water with it. Furthermore, this boiler like a well-managed household, has a place for everything and everything is in its place, and has numerous other advantages, as follows:

First. It has an ample combustion chamber directly over the fire grate.

Second. It is so arranged that it has a separate supply of fresh air above the fire.

Third. A separate steam space, so that the water cannot encroach upon the steam space, nor steam on the water space.

Fourth. A large water space and the flues so spaced as to ensure of a vigorous circulation.

Fifth. The boiler rakes toward the large end thus insuring that all sediment will gravitate to the lowest point to which the blow-off pipe is attached, and from which it is easily removed by blowing off.

Sixth. The rake or incline of the boiler gives a greater amount of impinging surface for the hot gases to act on.

Seventh. The angle of the back head also gives additional impinging surface.

Eighth. The front head on account of its angular position admits of an earlier and easier release of the gases from the flues.

FITTINGS.

The fittings comprise modern and most approved appliances for safe and economical operation, and include cast iron front, ash-pit, fire and flue doors and frames, with registers to prevent the formation of smoke, also water gauges fitted with glass tubes in duplicate steam pressure gauges, check, feed and blow-off valves and duplex safety valves.

DISCUSSION.

Mr. HUGO BILGRAM:—The advantages of high pressure have been very clearly shown by the speaker, but I think it proper to say that there are practical limits to the application of high pressure. The statement is made that the highest economy would be reached by expanding down to a perfect vacuum. This is only correct when we disregard the resisting forces of friction; but as we cannot run an engine without having to overcome that resistance, there is a limit to the advantage gained by further expansion. This limit is reached when the pressure of the steam on the piston equals the average rate of friction reduced to the surface of the piston. Therefore we have on the one hand a limit of the use of expansion. A similar limit can be shown to exist on the high pressure side of the diagram. The highest pressure is applied just when the crank is near its centre, where the motion of the shaft is greatest in proportion to the motion of the piston. The attending friction consumes a considerable percentage of the power, and since for a higher initial pressure the diameter of the crank shaft must be increased, the consumption of power by friction from this cause will increase even more rapidly than the rate of the initial pressure. These limits may be determined by practical tests, or else by intricate calculations, but it is my impression that we use the steam in the present high pressure engine very near to these limits, especially in the compound engines, where high and low pressure cylinders are combined.

Mr. LE VAN:—In reply to Mr. Bilgram, I would state that in practice we have been able, with a condensing engine, using high pressure steam to realize 90 per cent. of the theoretical diagram with

the consumption of from 15 to 18 pounds of water per hour per horse-power. This cannot be done with low pressure steam. It is an every day occurrence in this city, with high pressure automatic engines without condensing to average 85 per cent. of the theoretical diagram. At the electrical exhibition some experiments made with this boiler, which supplied steam to what is known as the "Buckeye Automatic Engine," developed a horse-power with 26 pounds of water per hour. At the boiler trials during the Centennial exhibition, we thought it extraordinary if we produced a horse-power with 30 pounds of water. The difference between the two trials is that in the former we carried 100 pounds per square inch, whereas in the latter we carried but 70 pounds; therefore, in the last eight years we have decreased the consumption as twenty-six is to thirty pounds of water per hour per horse-power; so, independent of all the objections which Mr. Bilgram so forcibly stated, there is no doubt we have been able to realize a result of 90 per cent. I think, therefore, that high pressures have proved desirable.

Mr. HUGO BILGRAM:—I did not intimate that the high pressure of, say 100 lbs., as now used, instead of 60 lbs., would not be an advantage, nor did I intend to convey that impression. I meant to show a final limit to the efficiency gained by an increase of pressure. I admit that it may be possible that 120 lbs. instead of 100 lbs. are capable of giving still better results, but finally we must reach a limit beyond which we can gain no more.

DAILY CYCLE OF SOLAR MAGNETIC INDUCTION.—M. Quet considers that the induction produced by any system of electric currents, upon a particle m, of positive electric fluids, is perpendicular to the relative velocity, ov, of this particle, and to the direction, od, of the line of force which passes through the point, o, of the magnetic field. If f designates the force, and e represents the angle vod, we have $f = mdv \sin. e$.

The induction of the sun upon the mass, m, placed at the centre of the earth, will be directed toward the centre of the sun, or towards that of the earth, according as the electricity is positive or negative, or according as the austral magnetic pole of the sun is at the north or south of the ecliptic. For all other points of the earth the analogous forces will be sensibly equal and parallel to the foregoing. At each instant the electric fluids of the globe are therefore submitted to two systems of forces, one converging towards the centre of the sun, and the other towards the centre of the earth. Hence arise two cycles of magnetic variation, one having a mean solar day for its period, the other the synodic rotation of the sun around its axis.—*Comptes Rendus*, Oct. 20, 1884. C.

FURTHER EXPERIMENTS IN WEATHER FORECAST.

By Pliny Earle Chase, LL.D.

Since the early part of February, I have received from the Signal Service Bureau the tri-daily weather reports, as well as the daily weather maps. I have also extended my comparisons to Caswell's Meteorological Observations at Providence, from December, 1831, to May, 1860. The reports, the maps, and the comparisons, all show that the Haverford tests, in my "Experiment in Weather Forecast" (this Journal, April, 1885), are by no means exceptional, but that similar results are probably attainable in all parts of the United States. I therefore venture to formulate some of the principles of astronomical weather forecast, as follows:

1. The lunar modifications of barometric pressure tend to produce, *a*, high barometer and westward pressure at syzygy; *b*, low barometer and eastward pressure at quadrature; *c*, falling barometer between syzygy and quadrature; *d*, rising barometer between quadrature and syzygy.

2. The solar modifications, through the combined action of heat, attraction and "relative motion," tend to produce, *a*, high barometer and southward pressure at the octants before syzygy; *b*, low barometer and northward pressure at the octants after syzygy; *c*, falling barometer between *a* and *b*; *d*, rising barometer between *b* and *a*.

3. The influences may be most equally divided by counting as fair all weather which is either fair or clearing, and by counting as stormy all weather which is storm-breeding (including "pet days"), lowering or stormy.

4. Precipitation, during stormy periods, produces a partial vacuum, which is often supplied by an inrush of dry air, producing pet days.

5. The exceptional storms or stormy tendencies, during the prevalence of fair indications, are mostly anti-cyclonic in their origin.

6. The general tendencies, independent of local and monsoon influences, are, *a*, fair for the octants following quadrature; *b*, variable, with predominant anti-cyclonism, for the octants preceding syzygy; *c*, stormy for the octants following syzygy; *d*, variable, with predominant cyclonism for the octants preceding quadrature.

7. The tendency to increasing dampness is greatest, *a*, from the Atlantic Ocean, between two days before and three days after syzygy,

with a prevalence of anti-cyclonic currents; *b*, from the Gulf of Mexico, between two days before the first and fifth octants and one day before quadrature, if cyclonic currents prevail; *c*, from the Lakes, between quadrature and syzygy, when the prevailing currents are anti-cyclonic.

8. The reversals of tendencies are mostly due to long continued polar or equatorial currents. These currents are not apt suddenly to change their character. Therefore, by watching all the influences, sufficiently to see which are normal and which are abnormal, it becomes possible to make forecasts for two or more weeks in advance, which will be verified in four cases out of five.

9. The relations of the daily to the annual barometric oscillations, which were used in 1863 as a ground for estimating the Sun's distance ("Proc. Amer. Phil. Soc.," ix, 283-8; x, 375-6), seem to account for an average daily eastward movement of about 1° in monsoon influences, which has been pointed out by L. A. Sherman, editor of the "Port Huron Times" ("Amer. Meteorolog. Journal," Nov., 1884; "Port Huron Daily Times," Feb. 11, 1885).

The following summary shows the influences, for an entire month, which may be looked for between May 15 and June 15, 1885. It will give readers of the JOURNAL an opportunity to judge for themselves to what extent these influences may be used as a basis for forecast. Observers will confer a favor by communicating the results of their observations to the Secretary of the Franklin Institute.

May 15-17, May 28-June 1, June 12-15, 1 *c*, 2 *c*, 3 (stormy), 4, 6 *c*, 7 *a*, 7 *b*.

May 18-21, June 1-5, 1 *c*, 2 *d*, 6 *d*, 7 *b*.

May 21-24, June 5-8, 1 *d*, 2 *d*, 3 (fair), 5, 6 *a*, 7 *c*.

May 25-28, June 8-12, 1 *d*, 2 *c*, 6 *b*, 7 *a*, 7 *c*.

On account of the friction of surface winds, the influence of accelerating and retarding pressures (1, 2), is most often shown by the upper currents, when cirrus clouds are visible.

LIGHT CLOUDS OF THE UPPER ATMOSPHERE.—A. Badoureau supposes that in the upper regions of the atmosphere the temperature may be reduced nearly to absolute zero, and although the temperature is correspondingly reduced he thinks it probable that carbonic acid, nitrogen and oxygen may be there condensed into clouds analogous to those which are formed by watery vapor in the lower atmosphere.—*Comptes Rendus*, Oct. 20, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 7.—Drawbaugh's Telephonic Inventions.

(Concluded from page 331.)

As we have already stated, the apparatus just described belonged to the class of electro-magnetic telephones, or those in which the voice of the speaker is caused to vary the electrical resistance of a circuit in which is placed a voltaic battery or other electrical source. The electrical current, so modified, being transmitted to the further end of the circuit, reproduces the speech by the use of some suitable receiver.

Drawbaugh's next step in the invention of the telephone would appear to have been made some time late in 1869, or early in 1870, when he claims to have constructed another form of electro-magnetic receiver. This apparatus, which is shown in Fig. 8, is of interest from the fact that when afterwards modified so as to act as a transmitter as well as a receiver, it formed his first magneto-electric telephone.

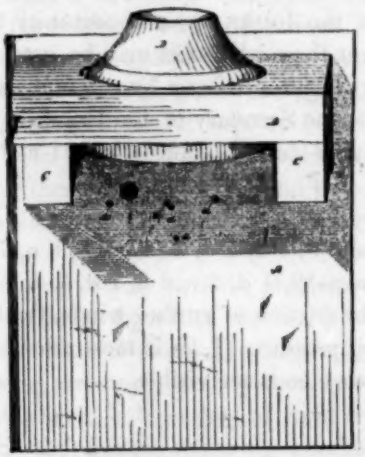

Fig. 8.—Drawbaugh's Electro-Magnetic Receiver.

Fig. 8 shows the instrument in its original form as an electro-magnetic receiver.

To the upright board *A*, which served as a support to the instrument, the blocks *C*, *C*, are firmly secured at right angles, and serve as a

support for the board *B*, through the centre of which the mouth-piece *D*, and the parts connected therewith pass. These parts were contained in the cylindrical box seen in the figure. Front and rear elevations of this apparatus are shown in Fig. 9, and a sectional view in Fig. 10.

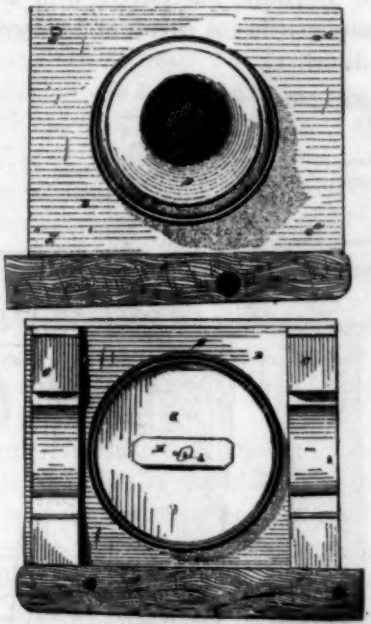

FIG. 9.—Front and Rear Elevation of Drawbaugh's Receiver.

The aperture of the mouth-piece was constructed as shown in Fig. 9, at *D*. Two diaphragms were employed in this receiver. These were placed parallel to each other, as shown in Fig. 10, at *E* and *G*.

FIG. 10.—Section through Receiver.

These diaphragms were connected together by a cord attached to their centres. The diaphragm, *G*, furthest from the outside of the mouth-

piece, was provided with the armature *H*, placed in the position shown. An electro-magnet was suitably supported with its poles near the armature, but not in contact therewith. The additional or accessory diaphragm, the one nearer the ear of the listener, or the one that was unprovided with an armature, was pierced with a number of holes. This instrument was placed in the circuit of a battery and the tumbler instrument already described.

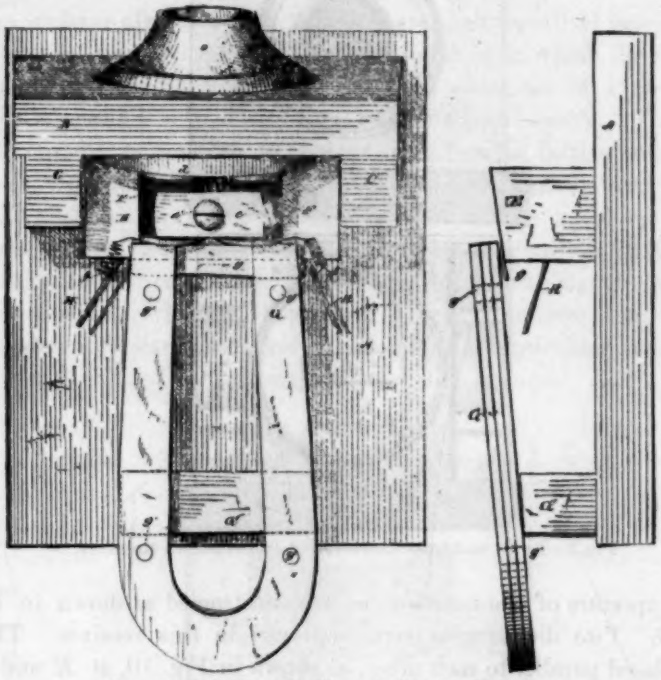

FIG. 11.—Drawbaugh's Magneto-Electric Telephone.

Drawbaugh appears to have modified this instrument shortly afterwards as follows; viz., he removed the accessory diaphragm and replaced the main diaphragm by a thin plate of German silver, to the centre of which was attached the armature *H*, as before. The interest in these instruments centres in the modification he claims to have made in the electro-magnet; for, removing the bar that connected the two cores, he joined them by means of a permanent magnet of horse-shoe form. The instrument, thus modified, became capable of being used as a transmitter, as Drawbaugh claims to have discovered during his experimentation. Most of the parts of the instrument, as originally

made, are, it is claimed, still in existence, and were produced in the famous interference suit already referred to.

The details of the apparatus, when in condition for use as a telephone transmitter as well as a receiver, are shown in connection with Fig. 11.

The base *A*, supports *C*, *C*, and *B*, and the mouth-piece *D*, are the same as shown in the last figures. The electro-magnet seen at *F*, *F*, is held in the position shown by means of the brass plate *e*, *e*, screwed to the base *A*. The piece of iron joining the lower poles of the electro-magnets *F*, *F*, is in this apparatus replaced by the permanent horse-shoe magnet *G*. This magnet was placed in the position shown with its poles in contact with the lower poles of the electro-magnets. *g*, is a piece of paper, and G^1, a block of wood on which the permanent magnet rests. Their relative thickness is seen in the side elevation shown on the right. The permanent magnet was of the compound type, united at g^1, g^1, g^1, g^1. The terminals of the coils of the electro-magnet are shown at *H*, *H*. The German silver diaphragm was held in place by means of the band *d*.

Assuming that the date of construction of this instrument can be established, then it not only anticipates Bell's patent of 1876, in showing a contrivance whereby the armature of an electro-magnet is set into vibration by the voice, and thereby produces undulations in the currents traversing the coil of the electro-magnet, such currents being in the same circuit with an apparatus capable of receiving them and correctly reproducing the original speech, but it also anticipates the essential claims of Bell's patent of 1877, since it shows means whereby the movements of a plate of inductive material before a permanent magnet with coils on the end of the magnet nearer the plate, can produce undulations in an otherwise continuous current traversing its coils, or can produce undulatory currents therein, although no currents were originally present.

Another instrument, made, as claimed, some time during 1871, was, like the preceding, originally designed for use with a voltaic battery as a receiver, but was afterwards provided with a permanent magnet, when it became operative as a transmitter and was employed by Drawbaugh as such. These latter changes appear to have been effected prior to July, 1873. This instrument was used in connection with the magneto-electric apparatus just described, and as might have been supposed, gave much better results than were attained by the use of the cup or

tumbler transmitter, and the earlier form of electro-magnetic receiver already described.

The details of this apparatus while used as a receiver only is shown in Fig. 12.

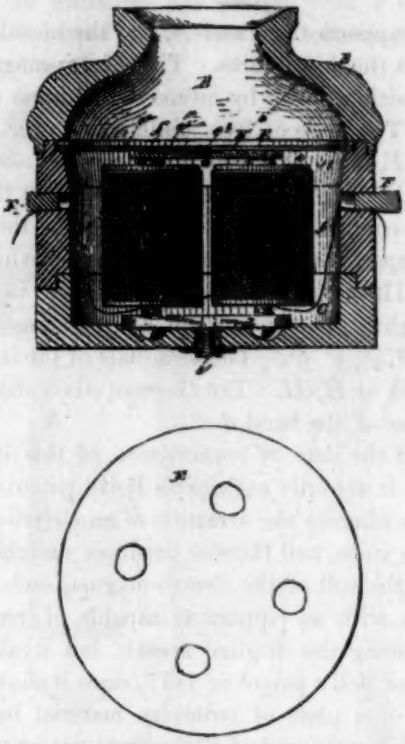

FIG. 12.—Drawbaugh's later Form of Receiver.

The mouth-piece, at *B*, has a comparatively wide air space between its open end and the diaphragms, of which latter there are two. The upper diaphragm, which is shown at *E*, was perforated in the manner seen in the lower part of the figure. The lower diaphragm, E^1, had an armature, *e*, attached to it by means of the screw e^2. This armature faced the poles of the electro-magnet *D*, *D*, and was near said poles but not in contact with them. A screw, e^1, holding the connecting bar *d*, apparently served for the adjustment of the magnet poles with respect to the armature. The wires of the electro-magnet passed out of openings in the case or box holding the instrument, and were held in position by means of the plugs *F*, *F*.

The modification of the instrument, whereby it acquired the power of acting as a transmitter as well as a receiver, is shown in Fig. 13.

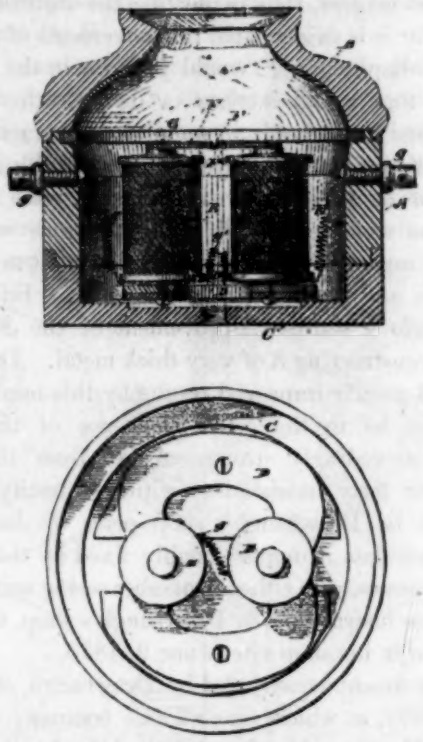

Fig. 13.—Drawbaugh's later Magneto-Electric Telephone.

In this case the upper perforated diaphragm is suppressed, apparently because it failed to produce the beneficial results anticipated.

The air space in the mouth-piece above the diaphragm was not modified at first, but subsequently considerable modification was effected in the shape and dimensions of the diaphragm, which was, as we have seen, the case with the later tumbler transmitter. The great change, however, as we have already intimated, consisted in the replacement of the connecting yoke *d*, of the last instrument, by permanent steel magnets, thus changing the apparatus into a magneto-electric telephone. This was effected by the disposition of permanent magnets, shown in the lower part of Fig. 13, where two curved steel magnets, *D*, have their similar poles opposite one another and joined by the soft iron

cores of the electro-magnet *E, E.* In this manner the cores of the magnet *E, E,* become permanently magnetized by induction from the poles of the steel magnet, thus permitting the instrument to act as a transmitter. For it is evident that the movements of the armature F^2, attached to the diaphragm *F,* would produce in the coils of wire on *E, E,* currents that would increase or decrease the current passing through them, and thus give it an undulatory character.

Some of the diaphragms employed by Drawbaugh, about the time of the construction of these latter instruments, were corrugated. It appears that the metal employed for diaphragms was too thin and required to be dampened. This Drawbaugh sought to effect by increasing the stiffness and rigidity by corrugation. Edison, it will be remembered made a similar improvement of the diaphragm in his instruments by constructing it of very thick metal. Drawbaugh claims that he obtained greatly improved results by this means.

The testimony as to the actual existence of these instruments appears to be exceedingly strong. Apart from the testimony of Drawbaugh, over forty independent witnesses testify to having seen the instruments in Drawbaugh's shop prior to June, 1875. The limit of the latter date is unquestionably fixed by the fact that fourteen of these witnesses, who either remember seeing and actually speaking through these instruments in Drawbaugh's shop, testified that they were never again in his shop after June 2, 1875.

The next instrument constructed by Drawbaugh, some time before December 23, 1874, at which time an axle company was started that did business in Drawbaugh's shop, is one of the first instruments made by him which he has preserved intact. This form is shown in Figs. 14 and 15, in longitudinal sections, and in front, rear, and side elevations.

In Fig. 14 is seen a front view of the instrument with the cap removed, and also views of the upper and lower sides of the diaphragm.

A, represents a hollow circular chamber provided with a thin wooden diaphragm *C,* securely kept in position by means of the cap *B.* An electro-magnet *D, D,* has its holes projecting into the hollow chamber *A,* and is supported by means of the brass bracket *F.* Opposite the holes of the magnet is the armature *d,* secured to the lower side of the diaphragm *C.* A brass screw B^1, passing through the front of the cover presses against a piece of soft rubber *c,* placed at the upper side of the diaphragm *C.* This piece of rubber was designed to act as a kind of dampening pad, to prevent the too free vibration of the

diaphragm. A mouth-piece at *I*, was provided near the upper part of the diaphragm. The screw *G*, passing through the bracket *F*, served to adjust the position of the bracket, and hence the position of the electro-magnet *D*, *D*.

As originally constructed, the mouth-piece was placed opposite the middle of the diaphragm. With this disposition of parts the diaphragm was found to vibrate too freely, and the opening was shifted to the position shown in the figures, and the dampening pad placed against the centre of the diaphragm. These changes were made about a year after the instrument was first constructed. This instrument, it will be observed, has no permanent magnet.

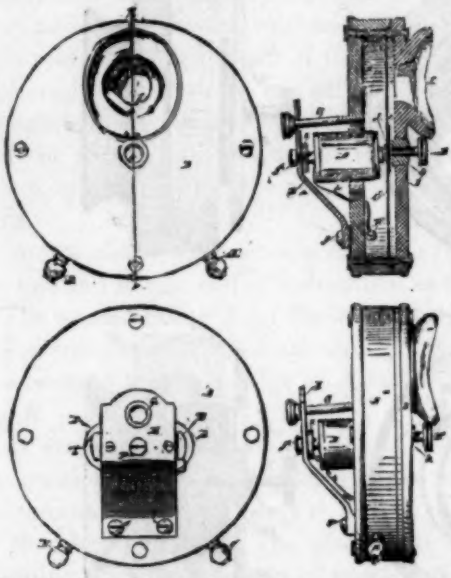

FIG. 14.—Drawsbaugh's Telephone, constructed prior to Dec. 23, 1874.

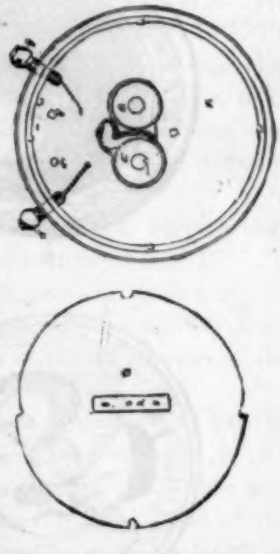

FIG. 15.—Drawbaugh's Telephone constructed prior to Dec. 23, 1874.

As to its efficiency, it is declared by an expert of undoubted ability to be an operative instrument, or "a highly organized magneto-receiver, with a neutral magnet."

Concerning its actual existence at the time claimed by Drawbaugh the evidence in this remarkable case appears to be almost overwhelming, unless it be assumed that the witnesses are deliberately perjuring themselves. This, however, their well known character renders extremely improbable. No less than forty-four witnesses testify to having seen the instrument in Drawbaugh's shop prior to the date of Bell's first

patent, viz., February 14, 1876, of this number, thirty-two testify to having seen the apparatus prior to June 2, 1875, and sixteen of these prior to January, 1875.

As to its practical value, fifteen witnesses testify to having actually employed, in Drawbaugh's shop, the apparatus just described for the reception of articulate speech, prior to February 14, 1876; and since some of these latter testify that they were never again in Drawbaugh's shop since June 1, 1875, the date of actual use would appear to be thus carried back prior to June, 1875.

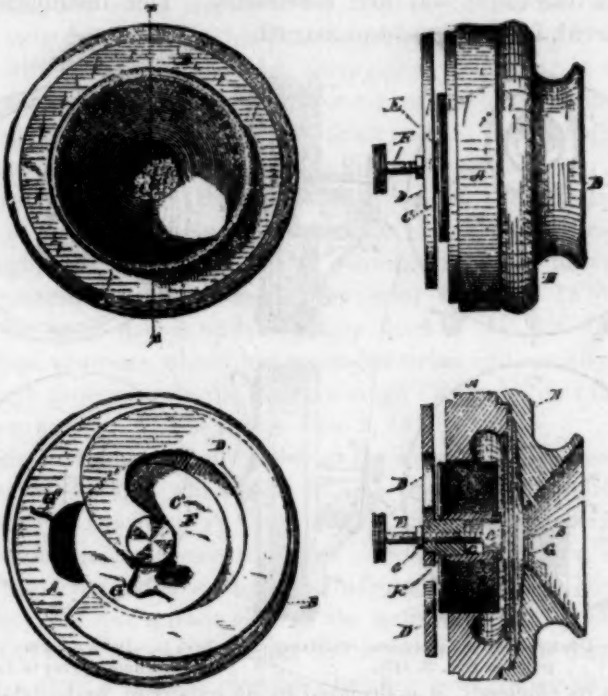

Fig. 16.—Drawbaugh's Magnetic-Electric Telephone of 1874–1875.

It will be noticed that the three different forms of apparatus we have just described as following the original cup and tumbler transmitter, and the original electro-magnetic receivers, were variations of receivers. Although it is true that the introduction of permanent steel magnets in most of them permitted them to be used as transmitters as well, and thus marked an era of great improvement, yet the effort appeared to be directed mainly to the improvement of the receiving

part of the apparatus. Nor does the order of this development appear at all improbable. Having by the construction of the cup or tumbler instruments produced a highly efficient form of transmitter, he naturally turned his attention to the construction of forms of apparatus suitable for use in connection therewith. This would appear to us the natural order, and as we have already seen was the order followed by many of the other inventors in telephonic apparatus.

The next set of telephones, claimed as invented and constructed by Drawbaugh, appear to be of the magneto-electric type. Parts of these instruments were made by Drawbaugh himself; the remaining parts were made under his instructions. These instruments appear to have been made in the latter part of the winter of 1874, and early in 1875. The original instruments are still in existence. The party who aided Drawbaugh to construct them testifies that he could at any time, from early in 1875, up to the present (1884), have reproduced these machines, except, perhaps, the proper proportions as to size of different parts.

One of these instruments is shown in front and side elevations at the top, and in rear and side elevations at the bottom of Fig. 16.

The wooden casing *A*, of the instrument, is provided with a cap *B*, and mouth-piece B^1. A diaphragm *G*, of tinned iron is securely fixed in a recess at the upper edge of *A*, and held in place by means of the cap *B*.

An electro-magnet *C*, consisting of a single hollow core *c*, is fixed in the position shown in an opening in the rear of the casing *A*, of the instrument. Soft iron plugs c^1, and *E*, pass through the hollow core of the electro-magnet. The plug c^1, is attached to the end of the adjusting screw *F*, by means of which it is readily moved towards or from the tinned iron diaphragm. The plug *E*, serves to support the screw *F*. A small jam nut *e*, is provided for holding *F*, firmly in place when once adjusted. The permanent magnet *D*, shaped as shown, has one of its poles securely connected to the rear pole of the electro-magnet *C*. This apparatus was therefore capable of use both as a transmitter and as a receiver.

The other magnet-electric instrument of 1874–1875, is shown in front and side elevations at the top, and in rear elevations (cap off) and in section at the bottom of Fig. 17.

This instrument, it will be observed, is similar in its general con-

struction to that just described. It differed, in that it was provided with a rear cap *C*, which encased the permanent magnet and adjoining parts. An aperture *h*, through the centre of the cap, permitted the the regulation of the movable plug through the adjusting screw.

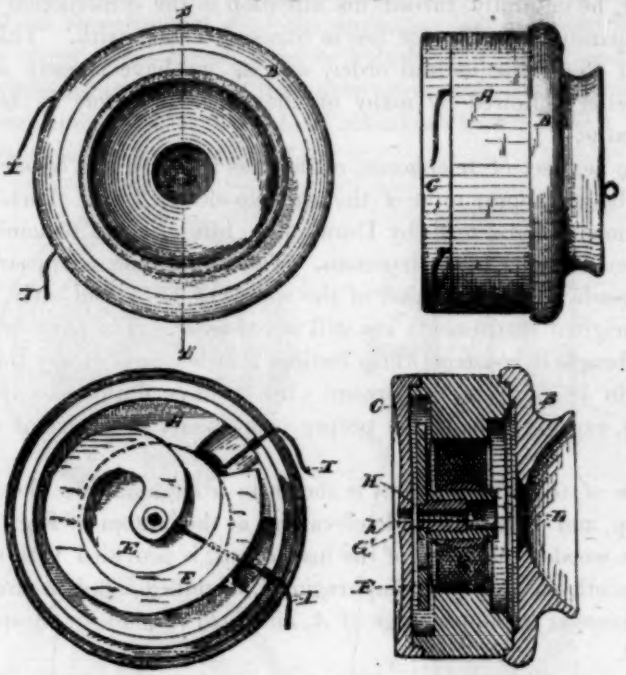

FIG. 17.—Drawbaugh's Magnetic-Electric Telephone of 1874-1875.

Concerning the operation of these instruments, a well-known expert, appearing for Drawbaugh in the previously-mentioned suit, testifies us follows:

"The instruments '*D*,' and '*E*,'" (those we have just described in connection with Figs. 16 and 17), "show the magneto-telephone in as compact a form as it has ever been constructed up to the present time. The magnet is flattened and curled, so as to occupy the least possible space; the means of adjusting the distance between the core and diaphragm is simple, positive, and easily controlled; and the instruments themselves, as I have proved, are excellent working speaking telephones on a circuit without a battery. They embody all the elements going to make up a speaking telephone, as described in Bell's two patents in suit. And, in fact, I see no reason why, if these machines were now manufactured and were upon the market, they would not, so

far as form, construction and and operation are concerned, successfully compete with any form of magneto-telephone now in vogue."

So, too, the witness for the complainants in the same suit, a well-known expert, testified after a trial of one of the instruments, the one described in Fig. 17: "I think that instruments like *E*, might be successfully employed for practical use, especially if there were no better ones to be had. The articulation of *E*, seemed to be very good, but the sound was wanting in volume and loudness."

Assuming that the above instruments were actually constructed at the date claimed, it will appear that Drawbaugh had, at that comparatively early day, made a progress in the improvement of the telephone that seems almost marvelous, and which it would be difficult to regard as probable were it not for the extent and nature of the testimony, both independent and corroborative, concerning the apparatus in question. For, it appears by the printed testimony, that some twenty-seven witnesses, independently of Drawbaugh himself, testify to have seen these instruments at some time prior to February 14, 1876. Most of them, indeed, testify to have seen them before June 2, 1875, and many of the witnesses claim to have actually talked through the apparatus, transmitting and receiving intelligible speech thereby. It is difficult to believe that so many independent witnesses could all be mistaken concerning the same thing, and it is equally difficult to believe that they could be testifying falsely, so that it would appear that the instruments were made at the date claimed.

The fact that Drawbaugh, supposing his claims to be true, had at so early a date a highly organized instrument, capable of such extended and valuable commercial applications, without ever even patenting it, or obtaining for it a wider notoriety, naturally suggests grave doubts as to the probability of the actual truth of the facts as claimed. It should be borne in mind, however, in Mr. Drawbaugh's behalf, that a considerable time elapsed after Mr. Bell brought the articulating telephone into general public notoriety, before its real value or practical applications were thoroughly appreciated. So little, indeed, did Mr. Bell appear to think of that portion of his application of February 14, 1876, which is claimed to cover the principle of the electrical transmission of speech, that nowhere in said specification does he clearly express the fact that it was one of the objects of his invention to transmit speech electrically. The failure of Mr. Drawbaugh, therefore, to patent his inventions, or to bring them into general public use, though naturally suggestive of

doubt as to the probability of his having actually made the inventions at the time claimed, yet the doubt thus suggested is by no means conclusive as against Mr. Drawbaugh. Such doubts, it may be added, are, it would seem, almost, if not entirely removed, by the apparently overwhelming evidence as to the correctness of Mr. Drawbaugh's assertions.

It may be remarked that, apart from the testimony as to the inventions of Mr. Drawbaugh, which we have thus briefly described, there would appear to be no internal evidence of improbability arising from the order in which he claims to have evolved them. Their order of evolution appears to be quite natural, as we think the following shows.

The early experiments begin with varying resistance transmitters as are illustrated in the old tea-cup instruments. In this respect he begins where, in the opinion of some, Reis left off, and where Edison began his experimental work in telephony. The step taken by him in obtaining experimentally the best conditions for success in this direction would appear to us to show no little skill and intelligence as an investigator. He followed, at that early day, substantially, the steps afterward independently taken by Edison in the development of his carbon transmitter, and produced an instrument substantially like it. His early form of electro-magnetic receiver, crude and awkward at the start, with its membraneous diaphragm, string connection, and the spring support for the armature, gradually gave place after repeated trials to the single metallic diaphragm, with the diminished air space on the side brought next to the ear.

Then follow his later magneto-telephones, suggested most probably by trying to use his receivers as transmitting instruments. His early forms were naturally crude, and the parts inconveniently assembled. The fact that so much of them was exposed led to their being frequently put out of the adjustment necessary to their efficient operation. He therefore produces a more compact instrument, and encloses it in a suitable case. Experimenting with large diaphragms, probably with the idea of obtaining greater strength of the sounds, he experiences difficulty in false vibrations, and avoids them by the device of placing the mouth-piece out of the centre of the diaphragm, at which place he puts a dampening pad. Finally, however, he realizes that no advantage is to be derived from large diaphragms and he produces the exceedingly compact and efficient instrument shown in Fig. 17.

Besides the apparatus we have described, all of which are claimed to have been produced prior to the date of Bell's application for Letters

Patent, viz., February 14, 1876, Drawbaugh subsequently produced numerous other instruments, similar to many of those now in general commercial use. Since, however, we are at present interested mainly in the early history of the telephone, the instruments already described will be sufficient to enable the reader to appreciate the exalted position that Mr. Drawbaugh claims to occupy in the history of the articulating telephone.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, March 13, 1885.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April* 15, 1885.]

HALL OF THE INSTITUTE, April 15, 1885.

Vice-President, FRED'K GRAFF, in the chair.

Present—282 members and 75 visitors.

The election of ten new members since the last meeting was reported.

The Chairman of the Committee on Science and the Arts reported that the Committee recommend the award of the "John Scott Legacy Premium and Medal" to C. J. H. WOODBURY, of Boston, for his apparatus and system of securing safety in the Use of the Electric Light in Mills, etc., and to CHRISTIAN E. METZLER and JOHN H. BURRELL, JR. of Philadelphia, for their improvements in Signal-Lanterns for Railways.

The recommendations of the Committee were approved, and the Secretary was directed to report the action of the Institute to the Board of City Trusts.

Prof. WILLIAM H. GREENE exhibited by projection on the screen some curious and interesting experiments illustrating the continuity of the liquid and gaseous states of matter.

The apparatus consisted of a series of glass tubes containing carbon dioxide under very great pressure. At temperatures below 87°F. the tubes contain the substance as a liquid, but above 88° no amount of pressure will cause the gas to become liquid. At 87·7°, and under a pressure of 73 to 75 atmospheres, it is in a critical condition, in which the attractive force of the gaseous particles is exactly balanced by the repelling force of heat, and the least lowering of temperature causes an imperceptible transition to the liquid state.

Col. WILLIAM LUDLOW, Chief Engineer of the Water Department of Philadelphia, then gave, by request, his views respecting the Future Water Supply of the City. The subject was freely discussed by Prof. E. J. HOUSTON, FRED'K GRAFF and HECTOR ORR. The report of the same has been referred for publication.